

THE SCOVILLE SPLICE LIBRARY · THE CUISINES

Engineered Mexican

The whole chile canon, ancho to habanero. *Heat, laddered.*

The chiles of Mexico — read on the Index, laddered by the gene, and cooked by the number — with every salsa, adobo, and mole scored as you make it. A receptor-level account of the oldest flavor language on earth, and of learning, at last, to speak it on purpose.

SCOVILLE SPLICE · GROWN BY OUR FAMILY. ENGINEERED FROM SCRATCH.

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Opening essay · The Chile Is a Language

> Mexico did not discover the chile. Mexico taught it to speak.

Six thousand years ago, in valleys not far from where the markets still stack their chiles in dark pyramids, the first people to keep the seed of the fruit that moved them began the oldest act of flavor design we know of. *Capsicum* was domesticated here, in Mesoamerica, long before it was anything to the rest of the world — the archaeobotany puts the first cultivated peppers in central-east Mexico by roughly 6,000 years ago, ground into pots and carried north and south from this one hearth. And the cooks of this place did with it what no one else had: they made it a vocabulary. Not one chile but dozens, each a separate word. Ancho for the sweet raisined dark. Guajillo for the bright, tannic berry. Pasilla for the herb and the dried-plum hush. Chipotle for smoke and leather. Árbol for the clean sear. Habanero, up in the Yucatán, for fruit and flowers and fire all at once.



The inside of a chile, cut: the pale placental ribs where the fire is actually made, and the seeds that carry almost none of it.

Underneath every one of those words is the same molecule — capsaicin — meeting the same nerve ending: **TRPV1**, the ion channel on the trigeminal fibers of the tongue that also answers to real heat above 43 °C and to the acid of a held breath. The molecule does not warm the tissue. It lowers the channel's own thermal threshold, so the body, briefly and gloriously fooled, reports a fire that is not there and harms nothing. That is the trick at the bottom of this entire cuisine: a sensation of damage with no damage done, offered across a table as a pleasure. But the genius here was never only the burn. It was everything the cooks learned to carry *alongside* the burn — the

fruit, the smoke, the earth, the round deep body of a mole simmered half a day, the tannic grip of chocolate, the bright sting of canela. For all of that artistry, across all those centuries, there was never a number. "Medium heat" was a hope passed from one pair of hands to the next. A mole was a memory you could not write down, and so could not be made twice exactly the same.

The Iyengar Flavor Index gives the canon its first grammar. Heat becomes a single figure on one axis, **IFI-H**, anchored to the receptor and not to a memory — so that a sauce tastes the same in August and in February, in Oaxaca and in a kitchen that has never seen an Oaxacan market. And because the chile was always more than heat, seven other axes stand ready to hold the rest of it: the fruit on **IFI-S** (sweetness, through the **TAS1R2·TAS1R3** receptor pair), the savory pull on **IFI-U** (umami, through **mGluR1**), the bitterness we quiet out of a hard-toasted skin on **IFI-B** (through **TAS2R38**), the round body of the long simmer on **IFI-K** (kokumi, through the calcium-sensing receptor **CaSR**), the bright herbal sting of oregano and canela on **IFI-P** (pungency, through **TRPA1**), the tannic finish of chocolate and tomatillo on **IFI-A** (astringency, read by the salivary proline-rich proteins), and the rare cool lift on **IFI-C** (through **TRPM8**). One line sits underneath all eight:

$$\mathrm{IFI}(\text{candidate}) = 1{,}000 \times \mathrm{EC}_{50}(\text{reference}) \div \mathrm{EC}_{50}(\text{candidate})$$

EC_{50} is the concentration at which a stimulus drives its receptor to half of full response — the lower the number, the louder the molecule. Invert it against a fixed reference, scale by a thousand, and loudness becomes a score you can cook toward: 1,000 is the half-activation of the wild-type reference, and everything else is read as how much louder, or softer, a thing speaks on that one channel. We did not build the Index to replace the poetry of this food. You cannot improve on *mole poblano*. We built it because you cannot design — or reliably repeat, or honestly ladder — what you cannot measure.

We are a family that has cooked out of this tradition our whole lives, and we did not come to improve it. The canon does not need improving. The computing was one pair of our hands; the table it serves, and the reverence it carries, belong to all of us. We came to be able to *read* the language — to measure the thing the old cooks could only feel — and then, where a dish asks for it, to write within the grammar on purpose: to hold an ancho's fruit exactly while moving its heat to where a particular table wants it, to toast a mole brave without letting it turn bitter, to set one bowl of salsa in the middle of a table of mixed tolerances and have it reach everyone at it. This is a book about the oldest flavor language on earth, and about learning, at last, to speak it with intention — and about the quiet thing that runs under all of it: that food grown and cooked with this much care should also carry the most nourishment it can, the way the lime-steeped kernel of corn always did.

Eight axes are enough because eight receptors do nearly all the work. That is the quiet audacity of the Index — not that taste is simple, but that the tongue reads the molecular world through a small, countable set of locks, and if you have cut a key for each one,

you can in principle write any flavor. Heat and its sharp cousin pungency; sweetness and the savory pull of umami; the richness of kokumi and the subtraction of bitterness; the cool lift and the tannic grip. Mexican cooking happens to exercise more of those eight at once than almost any cuisine on earth, which is exactly why it is the right place to prove the whole grammar. And we write it as *we* because that is the truth of the work: the computing was one pair of our hands, late at night, but the table it answers to — the questions that came up over dinner, the chiles toasted by someone who learned it from someone — belongs to all of us. A family wrote this, reverent about the plant and the receptor in equal measure, and meaning every number as a form of care.



PART I OF V

The Language of the Chile

Capsicum · TRPV1 · the capsaicin pathway · Pun1 and the double variant

Chapter 1 · The Chile Canon — *the vocabulary, read on one axis.*

Lay the dried chiles out the way the markets do and you are looking at a spectrum — not of color, though the color runs from brick to oxblood to near-black, but of heat, read left to right. For six thousand years the ruler under that spectrum was memory: a cook knew the gap between a guajillo and a serrano the way she knew the weight of her own hand, and she taught it to the next cook over ten years of standing at the same comal. The Index lets you print the ruler underneath. Here is the traditional canon, each chile measured where it actually lands on IFI-H, with the heat it has always carried and the single word it has always spoken — and, at the bottom, where our own engineered ladder begins and ends.

CHILE	FORM	SPECIES	TRADITIONAL SHU	IFI-H	THE WORD IT SPEAKS
Ancho	dried poblano	*C. annuum*	1,000–2,000	55	sweet, raisin, dark
Mulato	dried poblano	*C. annuum*	1,000–2,000	55	chocolate, licorice
Pasilla	dried chilaca	*C. annuum*	1,000–2,700	70	herb, dried plum
Guajillo	dried mirasol	*C. annuum*	2,500–5,000	110	bright, berry, tannic
Poblano	fresh	*C. annuum*	1,000–2,000	55	green, meaty, mild
Jalapeño	fresh	*C. annuum*	2,500–8,000	150	green, grassy
Chipotle	smoked jalapeño	*C. annuum*	2,500–8,000	180	smoke, leather
Serrano	fresh	*C. annuum*	10,000–25,000	330	clean, high, grassy
Chile de árbol	dried	*C. annuum*	15,000–30,000	430	sharp, searing, direct
Habanero	fresh	*C. chinense*	100,000–350,000	900	fruit, flowers, fire
Ember · SS-0087	engineered	*C. chinense*	~866K†	1,570	where our ladder begins
Phoenix · SS-0096	engineered	*C. chinense*	~2.95M†	4,200	the top of the world

† *Engineered-cultivar SHU values are computational predictions from our flux model, not certified measurements.*

Two things are worth reading slowly in that table. The first is the naming. Mexico is nearly alone among cuisines in giving a chile a second name when it is dried, because drying changes the fruit so completely it becomes a different ingredient: a **poblano** becomes an **ancho** (or a **mulato**, from a darker-ripening strain); a **chilaca** becomes a **pasilla**; a **mirasol** becomes a **guajillo**; a ripe **jalapeño**, smoked, becomes a **chipotle**. The fresh name is a vegetable; the dried name is a spice. No other kitchen on earth thinks about one plant in so many tenses, and it is the clearest evidence that this is a cuisine that treats the chile as a language and not an ingredient.



The pepper, whole: one plant that the canon reads in a dozen tenses — green and fresh, ripened red, dried to leather, smoked to mahogany.

The second thing is the species line. Almost the entire everyday canon is *Capsicum annuum* — the great domesticated workhorse that gives us poblano, jalapeño, serrano, guajillo, árbol, and the rest. The habanero is the exception: it is *Capsicum chinense*, a separate domestication (its center of diversity is the Amazon basin, but the Yucatán adopted it so completely it is unthinkable without it), and it is the species where the real heights of heat live. That matters for everything that follows, because our own ten proof-of-concept superhots are all *C. chinense* — the habanero's lineage carried, gene by gene, to nearly three million Scoville. When this book ladders heat for a Yucatán table sauce and when it reaches for the top of the world, it is working within one species the Yucatán already made its own.

It is worth widening the lens past the everyday dozen, because the canon is deeper than any market stall shows. *Capsicum* was domesticated not once but five separate times across the Americas, and three of those species still cook in Mexico every day. *C. annuum* is the great workhorse already named. *C. frutescens* gives the small, upright, incendiary chiles — the *piquín* and *chiltepín* that grow half-wild and are, by many accounts, the closest living thing to the ancestral pepper the first farmers found, scattered by birds (which, lacking the mammalian TRPV1 response, feel no heat and so carry the seed). *C. pubescens* — the *manzano*, with its black seeds and apple shape and its tolerance of cold highland air — is the odd cousin, unmistakable and uncrossable with the rest. And the dried canon runs far past ancho and guajillo: the round, rattling *cascabel*;

the slender *puya*, a hotter guajillo; the *costeño* of the coasts; and, rarest and most treasured of all, the *chilhuacle* — black, red, and yellow — grown almost nowhere but the Cañada of Oaxaca and indispensable to that state's legendary seven moles, a chile so scarce it is effectively a controlled appellation enforced by nothing but geography and inheritance. Every one of them is a separate word, and every one lands at a readable point on IFI-H. The canon is not a list of a dozen peppers. It is a language with a lexicon, and we have only begun to transcribe it.

Read the ladder and you can read a map as well, because heat in Mexico is regional the way an accent is. The north, cattle-and-wheat country, cooks with a restrained hand — the gentle *chile colorado*, warmth as seasoning rather than statement. Central Mexico lives in the middle of the ladder, the everyday jalapeño and serrano and the dried chiles of the daily *guisado*. The Yucatán reaches for the habanero and the fruited top of the scale, then tempers it with sour orange. And Oaxaca cooks in a register all its own, where raw heat is almost beside the point and the chile is prized instead for color, depth, and the shadowed fruit it lends a mole. One country, one genus, and a dozen regional dialects of the same word — which is precisely why a single readable axis is so useful across all of it: it lets a cook in one dialect understand, exactly, what a cook in another meant by "hot."

Read the table and the canon stops being folklore and becomes a scale. The jump from guajillo to serrano is not a vague "hotter" — it is roughly 110 to 330, a tripling the tongue registers not as *more* but as a different order of sensation, the way a tripled sound is heard as a new volume rather than the same volume louder. The old cooks knew that gap by heart and taught it by the decade. The number teaches it in an afternoon, and — more to the point of a book that brands and restaurants will cook from — it lets a sauce made in one city carry the exact heat a cook in another built by feel. That is the whole gift of the first column of this book: the chile, at last, made legible. Everything after it is what you can do once you can read.

Chapter 2 · TRPV1 and the Mathematics of the Burn — *the receptor, exactly.*

To ladder heat honestly you have to know precisely what heat *is*, and heat is not a property of the chile. It is an event in a protein. **TRPV1** — the transient receptor potential vanilloid-1 channel — sits in the membrane of the polymodal nociceptors that wrap the tongue and the lining of the mouth, the free nerve endings whose entire job is to report injury. It is a non-selective cation channel: when it opens, it lets sodium and, critically, calcium pour through the membrane, and that ionic rush is the depolarization the brain reads as *burn*. The channel is a sensor of genuine threat. It opens to temperatures above about 43 °C, to protons when tissue goes acidic, and to a short list of molecules — vanilloids — that happen to fit a pocket on its intracellular face. Capsaicin is the most famous of them.

Here is the sleight of hand that makes a chile feel hot without any heat. Capsaicin does not raise the temperature of your mouth by a fraction of a degree. What it does is bind that vanilloid pocket and *lower the channel's thermal threshold* — drag the temperature at which TRPV1 fires down from 43 °C to somewhere near body temperature, so that the warmth already present in your mouth, which the channel would normally ignore, is suddenly enough to open it. The fire is real as a signal and fictional as an injury. Nothing is burned. The body sounds an alarm for a threat that has already left, which is exactly why the sensation is safe enough to have become a pleasure and a cuisine.



A superhot in cross-section: the capsaicinoids are made and stored in the pale placental ribs along the inner wall, not — as nearly everyone believes — in the seeds.

Two facts about where capsaicin lives correct a myth and set up the engineering. First, the capsaicinoids are synthesized and stored in the **placental tissue** — the pale ribs and the septum along the inner wall of the fruit — in vesicles on the surface of that tissue, not in the seeds. The seeds taste hot only because they sit pressed against the placenta; scrape the ribs out and you have taken nearly all the

fire with them. Second, "capsaicin" is really a small family. The two dominant members are **capsaicin** itself — the vanillylamide of 8-methyl-*trans*-6-nonenoic acid — and **dihydrocapsaicin**, its saturated twin, together roughly 90% of the capsaicinoids in a typical chile at about a 2:1 ratio, with nordihydrocapsaicin and a few others making up the rest. The length and saturation of that fatty-acid tail is not a footnote. It sets the *shape* of the burn: capsaicin, with its unsaturated tail, binds and releases faster — a sharp, front-of-the-mouth, quick-rising heat — while dihydrocapsaicin is slower and more persistent, a back-of-the-throat warmth that outlasts the meal. Two chiles of identical total Scoville can burn like two different events because their isomer ratios differ, and this is the first place the Index parts company from the old scale.

The channel those molecules pry open is, structurally, a thing of real beauty, and the structure explains the sensation. TRPV1 is a tetramer — four identical subunits arranged around a central pore, each contributing six membrane-spanning helices — and the vanilloid pocket into which capsaicin fits sits on the intracellular side, cradled between the S3 and S4 helices of each subunit. Cryo-electron microscopy has caught capsaicin in that pocket in a distinctive "tail-up, head-down" pose: the vanillyl head anchored deep by hydrogen bonds to a tyrosine and a threonine (the residues the literature numbers Y511 and T550), the acyl tail pointing up toward the membrane. When the head docks, it pulls on the S4–S5 linker, and that tug is transmitted mechanically to the gate that lets the cations through. This is why the shape of the molecule's tail matters so much to the burn: it is not decoration but leverage — the lever arm by which a bound capsaicinoid actually opens the gate.

The same pocket explains the cuisine's oldest mercy, that the second bite burns less than the first. Flood TRPV1 with capsaicin and the calcium pouring through triggers a feedback that *closes* the channel to further stimulation — a calcium-dependent desensitization the pharmacologists call tachyphylaxis. It is why a chilihead's tolerance is real and physiological rather than bravado: repeated exposure leaves the channels progressively harder to open, and over years the nerve endings themselves retract a little. The Index measures the fresh, un-desensitized response — the loudness of the first honest bite — because that is the only one worth designing toward.

Why not just use Scoville. The Scoville Heat Unit is a measure of *concentration by dilution*: historically, how many volumes of sugar water it took to render a chile extract undetectable to a panel of tasters; today, an HPLC measurement of total capsaicinoid content converted into those same units. It answers "how much is in there." The Index asks a different question — "how loudly does it speak at the receptor" — and the two are not the same question. IFI-H is anchored to the half-maximal activation of TRPV1:

$$\text{IFI-H} = 1{,}000 \times \text{EC}_{50}(\text{reference}) \div \text{EC}_{50}(\text{candidate})$$

where the reference is the wild-type capsaicin response, set so that 1,000 is its half-activation point. Because capsaicin and dihydrocapsaicin have different EC_{50} values at TRPV1 and different on/off kinetics, a chile's IFI-H weights not just *how much* capsaicinoid it carries but *which* capsaicinoids and in what ratio — the thing the tongue actually feels as the character of the burn. SHU and IFI-H track each other closely up the middle of the canon and then begin to diverge at the extremes and wherever the isomer mix is unusual, which is why our engineered ladder is specified in both: the SHU for the growers and the regulators who speak that language, the IFI-H for the cook who wants the burn to arrive in a particular place at a particular speed.

The lipophilicity of the molecule settles the oldest argument at the table. Capsaicin is fat-loving and water-fearing — its partition coefficient, logP, sits around 3.6 — which is exactly why a glass of water does nothing to put the fire out: you are chasing an oil-soluble molecule with a solvent it will not enter, merely sloshing it across more of the mouth. Milk works because casein, the fat-carrying protein in dairy, surrounds the capsaicin and lifts it off the receptor, which is why the *crema* on a Mexican table is not only richness but mercy, and why a mango *con chile* is handed over with lime and not with a cup of water. And for the record-keepers, the bridge between the two scales a grower and a chemist use is close to linear — about 15 to 16 Scoville Heat Units per part per million of capsaicinoid — which is how our model predicts a Phoenix fruit's roughly 190,000 ppm reads out as nearly three million SHU.

CHILE	HPLC CAPSAICINOIDS (APPROX.)	SHU	IFI-H
Ancho	~90 ppm	~1,500	55
Guajillo	~250 ppm	~3,500	110
Serrano	~1,200 ppm	~18,000	330
Habanero	~13,000 ppm	~200,000	900
Phoenix · SS-0096	~190,000 ppm (predicted)	~2.95M (predicted)	4,200

The cooperativity of the channel is the last piece of the math a cook should feel in the body even without naming it. TRPV1 opens with a Hill coefficient near 2, meaning the response does not climb gently with dose — it is sigmoid, with a steep middle. Below the foot of that curve a chile is barely warm; across the steep stretch a small increase in capsaicin produces a large jump in sensation; past the top the channel is saturated and more molecule buys almost nothing but duration. This is why heat laddering is so much more useful than it sounds: the interesting, cookable range of a table is packed into the steep middle of a sigmoid, where being able to place a cultivar at IFI-H 150 rather than 330 is the difference between a salsa the whole table shares and one half of it pushes away. You are not turning a dial on a chile. You are choosing a point on a receptor's activation curve — and the only way to choose it reliably is to be able to measure it.

Chapter 3 · The Pathway — *how a chile builds its fire.*

A chile builds capsaicin the way a kitchen builds a sauce: two preparations made separately and married at the end. The elegance of it — and the reason the method we use on peppers transfers to other plants at all — is that one of those two preparations is not special to peppers in the slightest. It runs in every vascular plant on earth.

That shared half is the **phenylpropanoid branch**, the ancient trunk-road of plant chemistry that also builds lignin, the pigments in flowers, and the vanillin in an orchid. It begins with the amino acid phenylalanine and walks it down a short, well-mapped series of enzymes:

STEP	ENZYME	IN → OUT
1	**PAL** (phenylalanine ammonia-lyase)	phenylalanine → *trans*-cinnamic acid
2	**C4H** (cinnamate 4-hydroxylase)	cinnamic acid → *p*-coumaric acid
3	**4CL** (4-coumarate-CoA ligase)	*p*-coumaric acid → *p*-coumaroyl-CoA
4	**HCT** (hydroxycinnamoyl transferase)	*p*-coumaroyl-CoA → caffeoyl shikimate → caffeic acid
5	**COMT** (caffeic acid *O*-methyltransferase)	caffeic acid → ferulic acid → **vanillin**
6	**pAMT** (putative aminotransferase)	vanillin → **vanillylamine**

The product of that road, **vanillylamine**, is the vanilloid "head" of the capsaicin molecule — the very part that fits the pocket on TRPV1. (It is also, one methyl group away, the vanillin of vanilla; we will return in the aromatics chapter to the fact that the fire and the sweetness Mexico gave the world are, down at the molecule, written by the same six enzymes.)

Two details of how the pathway is *controlled* matter as much as the steps themselves. The first is that the whole apparatus is switched on in one tissue only — the placenta — by a small set of transcription factors; a MYB-family regulator sits over the terminal genes, and its presence is why the ribs make fire while the rest of the fruit does not. This tissue-specific control is a gift to the engineer: tune the terminal step and you move the heat without touching the leaf, the root, or the plant's ability to feed itself. The second is that capsaicin, once made, does not accumulate forever — peroxidases in the same tissue slowly turn it over, oxidizing it into dimers and other products. Peak heat is therefore a *balance* between synthesis and degradation, a tap and a drain running at once, which is one more reason wild heat is so variable: a hot or dry season tips that balance either way. Fixing the synthase fixes the tap, and the ≤7% CV is in part the quieting of that lifelong tug-of-war.

The acyl "tail" branch rewards a closer look, because it is where the *shape* of the burn is set. The branched-chain amino acids are deaminated by BCAT to branched keto-acids, loaded onto an acyl-carrier protein, and elongated two carbons at a time through the KAS condensation cycle; a thioesterase finally releases the finished 8-methyl-6-nonenoyl chain for Pun1 to use. Lengthen or saturate that chain by a single step and you shift the capsaicin-to-dihydrocapsaicin ratio — and with it whether the heat is a quick bright strike at the front of the mouth or a slow swell at the back. The pathway does not just decide *how hot*. It decides *what kind of hot*, and both are now things we can read off the genome before a seed goes in the ground.

This is the moment to say plainly why a book about Mexican chiles keeps gesturing at tomatoes and corn. Of the platform's engineering modules, five of seven transfer unchanged to any plant with a sequenced genome — because five of seven act on that universal phenylpropanoid trunk, the road every vascular plant already paves. Only the four terminal enzymes are the pepper's private invention. So the method that reads and rewrites a chile's fire is not, at bottom, a method about chiles at all; it is a method about the shared chemistry of plants, proven first on the organism that happened to push that chemistry furthest. When a later chapter restores a tomato's umami, or imagines heat in a grass, it is not changing the subject. It is following the same road the capsaicin pathway walks for its first five steps, and turning off at a different exit.



The sequencer bench, where a chile's pathway stops being folklore: every enzyme above read off the genome before a single plant is grown.

The second preparation is the "tail," and this is the pepper-specific half. Branched-chain amino acids — valine and leucine — are handed by **BCAT** (a branched-chain aminotransferase) to a fatty-acid elongation loop run by **KAS** (a ketoacyl-ACP synthase), which stitches the carbons out to a branched, mono-unsaturated chain: **8-methyl-6-nonenoyl-CoA**. This is the acyl tail whose length and single double bond, from the last chapter, set the capsaicin-to-dihydrocapsaicin ratio and so the shape of the burn.

Then the marriage. **Pun1** — the capsaicin synthase, an acyltransferase also catalogued as **AT3** — condenses the vanillylamine head with the 8-methyl-6-nonenoyl-CoA tail into capsaicin itself, and stores the product in those placental vesicles. Four enzymes, then, are the pepper's own invention on top of the

universal road: **pAMT, Pun1/CS, KAS, BCAT**. Everything upstream of them is machinery any plant with a sequenced genome already runs — which is the entire thesis of the wider library, and the reason a tomato or a corn could, in principle, be taught to make heat at all.

Knowing the map is not the same as knowing where the traffic backs up, and for an engineer that second question is the only one that matters. Pouring more phenylalanine into the top of the road does nothing if the jam is at the end. So before touching a single gene we run a **genome-scale flux-balance model** of the whole plant — a stoichiometric accounting of every reaction the cell can perform, solved for the distribution of flux that maximizes capsaicinoid output under real metabolic constraints. Our flux model predicts that rate control sits upstream in the phenylpropanoid pathway — at **4CL** and **HCT/CCoAOMT** — not at the terminal Pun1/AT3 step. Pun1 is the final capsaicin synthase; it labels the product, it does not govern the rate. The head and the tail flow through; the upstream pathway architecture is where our model predicts the ceiling sits.

It is worth seeing the shape of that calculation, because it is the engine under every number in this book. A genome-scale model represents the cell as a stoichiometric matrix **S** — every metabolite a row, every reaction a column — and any steady state must satisfy **S · v = 0**, the mathematical statement that nothing piles up: whatever flows into each metabolite flows back out. Within that single constraint there are still countless admissible flux distributions **v**, so we choose one by linear programming — maximize capsaicinoid output subject to the real bounds on nutrient uptake, energy, and enzyme capacity — and then ask which one reaction, relaxed by a hair, lifts the ceiling most. That sensitivity analysis is the whole trick: it turns "where is the traffic jam" from a decade of field intuition into a solved optimization, and for the pepper it returns the same answer every time — rate control sits upstream, at 4CL and HCT/CCoAOMT, not at the terminal Pun1 step. That result reframes the engineering question: Pun1 is where the capsaicin molecule is assembled, the labeled endpoint of the pathway, and understanding it deeply matters — which is why the next chapter is entirely about that protein.

Chapter 4 · Reading Pun1 — *two mutations the breeders never found.*

Every breeding program that ever chased heat did it from the outside in: grow a field, taste the fruit, keep the seed of the hottest plant, and hope the genotype that made it hot came along with the phenotype you could taste. It works, slowly, and it drifts — because you are selecting on an output many genes away from the lever, and you never actually see the lever. We inverted the whole procedure. Flux balance told us where the ceiling sits and pointed us to Pun1 as the molecule to understand. So we went to the protein and read it directly, residue by residue, before growing anything at all.

The reading is done by a **protein language model** — an ESM2 network with 650 million parameters, trained on the evolutionary record of hundreds of millions of protein sequences until it has, in effect, learned the grammar of what folds and what functions. We hand it the Pun1 sequence and ask it to score *every possible single-residue substitution* — every one of the thousands of one-letter changes you could make to the enzyme — by predicted effect on two things at once: catalytic efficiency (does this change let the active site turn substrate into product faster?) and fold stability (does the protein still hold its shape, batch after batch, plant after plant?). The product of those two scores is the ranking. A mutation that speeds catalysis but wrecks stability is worthless; one that stabilizes a dead enzyme is worthless; we want the rare residues that lift both.

The model doing that scoring deserves a sentence on how it can possibly know. ESM2 is a transformer — the same architecture under modern language models — trained not on English but on the evolutionary record itself: hundreds of millions of natural protein sequences, with residues masked out and the network made to predict what belongs in the gap. Do that at scale and the model absorbs, implicitly, the grammar of proteins — which substitutions evolution tolerates and which it has spent a billion years forbidding. A variant's effect can then be read "zero-shot," with no laboratory data at all, from how much more or less probable the model finds the mutated sequence than the original: evolution's own odds, made legible. We layer a biophysical ΔΔG prediction over that evolutionary score to catch the stability half directly, and take the product of the two. The output is a ranked list of thousands of single edits, scored before a single plant exists — the exact inversion of a breeding program, which could only ever score the fruit long after the gene had done its work.

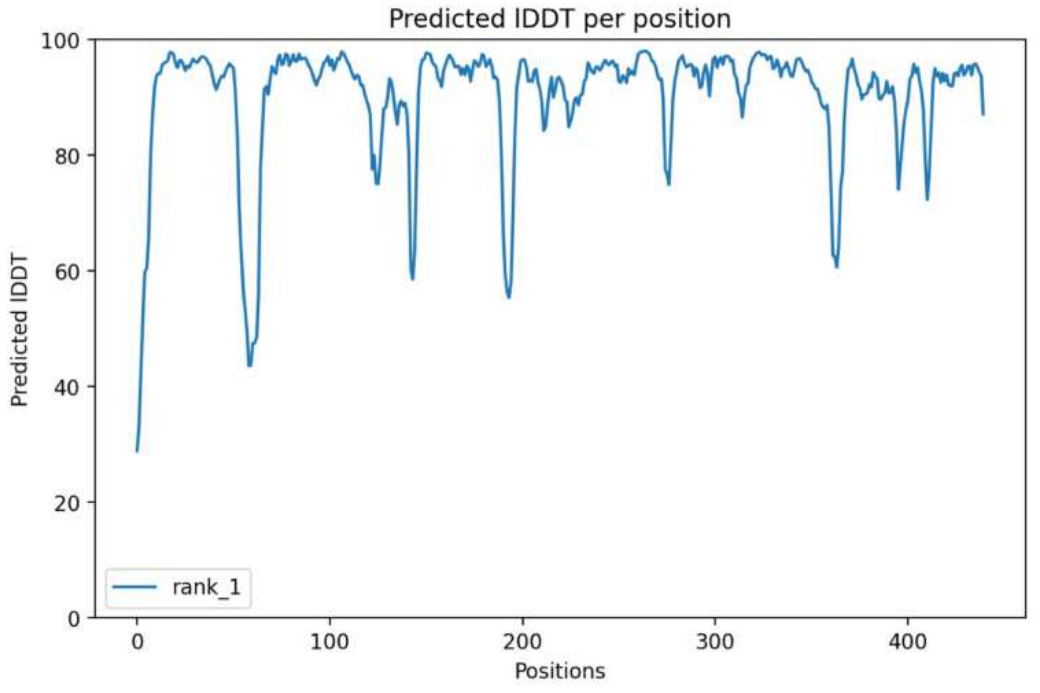


FIG. 4 — the Pun1 / AT3 model coloured by pLDDT confidence. The binding domain and the active-site cleft resolve at high confidence; the two shipped edits live where the model is surest.

Three substitutions came back from that search that no breeding program had ever found. Two of them — **S39L** and **L345G** — form the double variant written into the shipped construct; a third, C175S, is a structural annotation from our modelling (a disulfide-misfold prevention site) that was pulled from the final design. Written into the plant with CRISPR, the double variant S39L+L345G is designed to lift predicted peak output to approximately **2.95 million SHU** at a batch-to-batch coefficient of variation of **≤7%**, against the roughly **42%** variation a wild superhot swings through from plant to plant.

EDIT	EFFECT	ΔΔG (KCAL/MOL)
S39L	binding affinity ↑ at the N-terminal lip of the cleft	−2.1
L345G	steric relief inside the active-site cleft, freeing the acyl tail	−1.8
C175S *(structural annotation — not in shipped construct)*	removes a mispairing cysteine, preventing a disulfide misfold	−0.9

Read the ΔΔG column as the engineering in one number: each value is the change in folding free energy, and each is negative, meaning each edit makes the folded protein *more* stable, not less. That is the quiet triumph of the stability half of the model. The naive way to make an enzyme faster is to loosen it, and a looser enzyme misfolds — which is precisely why wild superhots are so inconsistent, swinging 42% because a fraction of every plant's capsaicin synthase has fallen apart before it could work. The two shipped edits, S39L and L345G, make the enzyme both faster *and* steadier, and the steadiness is what a sauce brand actually buys: a ≤7% CV means the hot sauce you formulate in spring tastes like the hot sauce you ship in winter, batch after batch, without a reformulation.

Writing the double variant in is its own discipline. CRISPR-Cas9 makes a cut at a location chosen by a short guide RNA, and the change is installed either by templated repair — a knock-in of the exact codon — or by a base editor that rewrites a single letter with no double-strand break at all; the guides are designed against the Pun1 sequence to land precisely there and nowhere else in the genome. The deeper reason these two substitutions were never

found by breeding is combinatorial, and it is worth sitting with. The edits are *epistatic* — their value depends on one another. The steric relief of L345G only pays off once S39L has drawn the substrate deeper into the cleft. Two specific residues out of a protein's hundreds, nearly worthless apart, sit at odds of millions to one against any phenotype-first search ever stumbling onto their combination. The protein language model did not search the field. It searched the sequence — and found in an afternoon what a century of patient selection could not.

The same protein that lets us reach the top of the ladder is what lets us build the rest of it. **Pun1 is the master switch of pungency** — the pepper's entire fire runs through it. The common sweet pepper is not a different plant; it is a chile carrying a loss-of-function deletion in Pun1, the last light simply turned off, which is why a bell keeps its fruit, its color, and its crunch and loses only the heat. Between full-off and our full-on lies the whole continuous ladder, and because we reach it by tuning a single, well-characterized locus rather than by stacking anonymous polygenes, we can place a cultivar *anywhere* on that ladder — IFI-H 55, or 150, or 330 — without disturbing the fruit, the aroma, the color, or the plant's own nourishment. A pepper is the one organism in our library that expresses on all eight axes, backed by **1,060 engineered constructs**; the heat axis alone is a dial we can now set to a number. The chapters that follow are what you cook once the dial is in your hand.



PART II OF V

Los Secos · The Dried Chiles

the patience of the comal · bitterness, subtracted · smoke · adobo

Chapter 5 · Los Secos — *fruit in the dark.*

The dried chiles are where this cuisine keeps its patience. A fresh chile is a vegetable with a clock running; a dried one is a spice that will wait a year. Drying is not merely the removal of water — it is a slow chemistry that the sun and the warm air perform on the fruit over days. As water activity falls, the sugars that were dilute in the fresh flesh concentrate and begin, gently, to caramelize; amino acids and reducing sugars inch into the early reactions of Maillard browning; the cell walls collapse to leather and the aromatics shift from green and bright toward raisin, prune, tobacco, cocoa. The heat, almost always, recedes behind the fruit. An ancho — a dried poblano — is barely hot, IFI-H near 55; what it *is*, is deep, a dark sweetness with the bass note of dried plum that no fresh chile can give you. The drying made the spice.

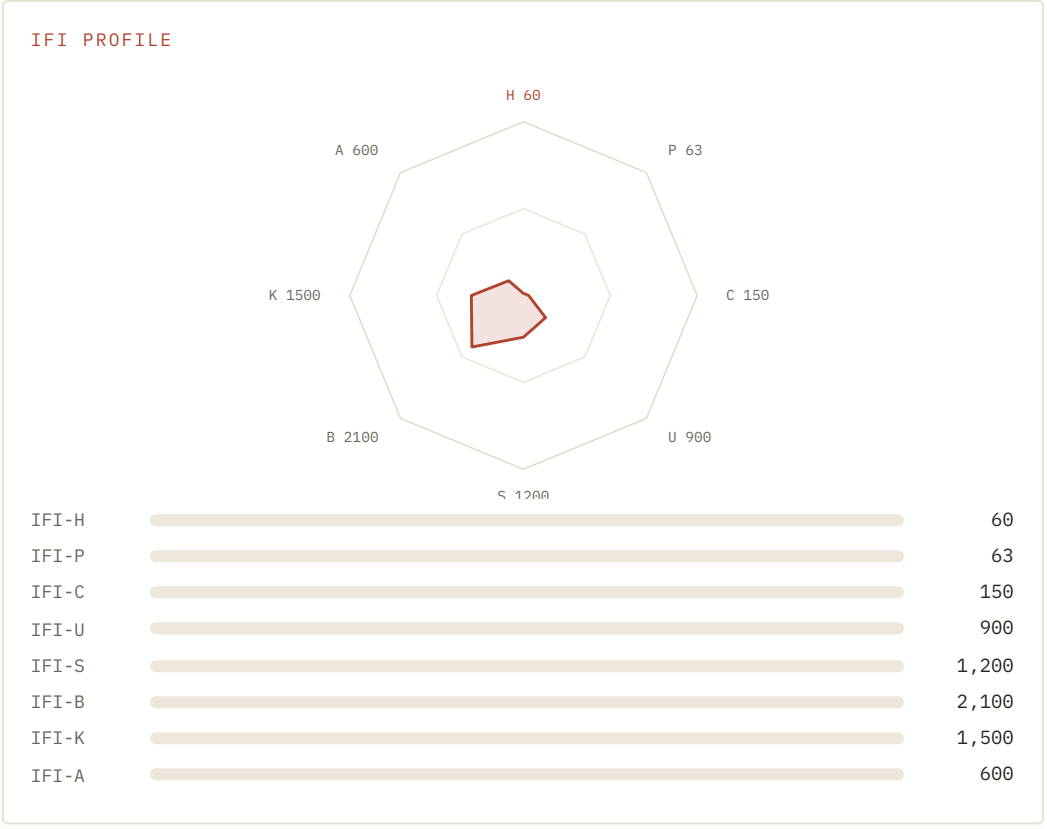


A dried superhot, isolated for the archive: the leather and the raisin are the sun's work, laid over a fire the plant built first.

Then comes the comal, and the comal is where the danger lives. To wake a dried chile you toast it, thirty seconds a side on a dry hot griddle, until it puffs and smells of nuts and smoke. Toast it a breath too long and bitterness floods in — the scorched skin generating the very compounds that fire **TAS2R38**, the bitter receptor evolution built to keep our ancestors from swallowing poison. Bitterness is the one taste the body reads as a warning by default, and a chile that has tipped from toasted into burnt turns acrid at the back of the throat and takes the whole sauce down with it. For most of history

the only defense was a cook's nerve and timing: toast boldly enough to wake the fruit, stop short of the char. Half a second of attention, repeated across a hundred chiles, every single time.

This is the axis the dried chiles most want help on, and it is the kindest one we tune, because **IFI-B is the only axis in the Index that subtracts.** Where every other axis adds a sensation, Zero-Bitter *removes* one: it attenuates the TAS2R38 signal at the source, by 20 to 65% depending on the cultivar, so the same molecules reach the tongue and simply speak more quietly. Turn the bitterness down and a chile forgives a harder toast — it steps its sugars and its fruit forward into the space the bitterness used to occupy. We lift the fruit a touch too, through the plant's own **TAS1R2·TAS1R3** sweetness pair, and build a little body in with **kokumi** so that a two-chile salsa tastes like it was simmered an hour. The heat we leave exactly where the ancho always wanted it: low, warm, a hand on the shoulder. Nothing is added to the chile that the chile could not make; the fruit stays an ancho's fruit. We have only turned down the one note that was never the fruit's to begin with — the one the fire of the comal wrote in.



An engineered ancho, tuned for the salsa pot: the fruit held exactly, the bitterness that only ever came from the fire turned down, so a dark salsa can be toasted brave and still taste sweet.

There is an old technique the Zero-Bitter axis quietly honors. Cooks have always known that a dried chile toasted too hard can be rescued, a little, by soaking the toasted chile in warm water and *discarding* that first bitter steep. It works because some of the bitter phenols are water-soluble and leach out. But it costs you fruit and color along with the bitterness — you are pouring flavor down the

drain to save the sauce. Tuning IFI-B at the plant does the same job without the tax: the bitterness is lower before the chile ever meets the water, so you keep the soaking liquid, keep the color, keep the fruit, and lose only what you wanted to lose.

Two more old disciplines sit around the dried chile, and both are quiet chemistry. The first is the toast itself: a dried chile is woken on a dry comal at a moderate heat for only seconds a side, pressed flat and turned the instant it puffs and its aroma blooms — long enough to volatilize the fragrant compounds and begin a little browning, short of the point where the thin skin scorches. The second is the soak. The toasted chiles are covered in *hot but not boiling* water and left fifteen or twenty minutes to rehydrate, because water that is merely hot swells the cell walls back to suppleness and draws the flavor gently into the liquid, while a hard boil would blow the cells apart and leach the color and fruit away in a grey rush. That soaking liquid is itself an ingredient — the first extraction of everything the drying concentrated — which is why a careful cook blends it back into the sauce rather than pouring it off. (And a word of plain care, since this is a book that means the body well: capsaicin clings to skin and will not rinse away with water, so the ribs of a hot chile are handled with gloves, and the hands kept well clear of the eyes.)

Salsa Macha

Makes about 1½ cups · 20 minutes · the Veracruz oil, half condiment and half confession

Salsa macha is the dried chile's masterpiece — not a fresh, bright sauce but a dark, nutty oil in which toasted chiles, garlic, and seeds are fried and then half-ground, a spoonful of which turns a plain egg or a bowl of beans into something you remember. It lives entirely on toasted depth, which means it lives entirely on the knife-edge of bitterness, which makes it the perfect first thing to cook from this book. We build it on an engineered árbol-and-ancho pair: árbol for a clean searing warmth, ancho for the raisined dark, both with their bitterness tuned down so the oil can be fried bold.

You need

6		chiles de árbol, stemmed
2		ancho chiles, stemmed, seeded, torn
4	cloves	garlic, sliced
3	tbsp	sesame seeds
1/4	cup	peanuts or pepitas
1	cup	neutral oil (or a good olive oil for weight)
1	tsp	flaky salt · 1 tsp cider vinegar

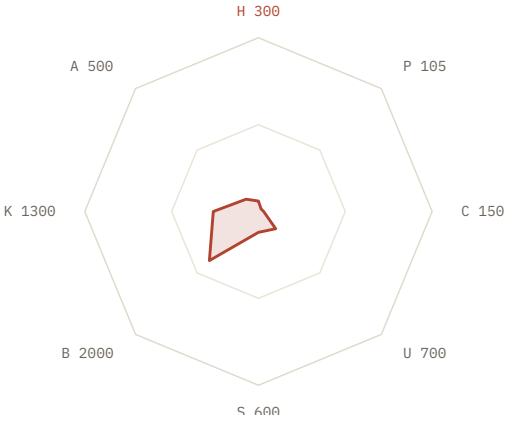
Make it

1. Warm the oil gently over low heat. Fry the garlic slices until pale gold and fragrant, then lift them out. Capsaicin is lipophilic — it dissolves into fat far more readily than into water — so the oil itself is doing extraction work here, pulling the heat and the fruit out of everything you fry in it.
2. Add the sesame and peanuts; fry until gold, then lift out. Fry the ancho pieces a few seconds until they darken a shade, then the árbol until just fragrant — do not let them blacken.

3. Cool the oil slightly. Combine everything — oil, chiles, garlic, seeds, nuts, salt, vinegar — and pulse to a coarse, spoonable rubble, not a smooth paste. Rest a day if you can; it deepens.

Why it works — Every element in the pan is a bitter risk: fried garlic, browned seeds, toasted chile skin. With the chiles' bitterness tuned to IFI-B 2,000 the whole oil reads as nutty, toasted depth rather than scorch, which means you can fry everything a shade bolder than nerve alone would allow — and bolder frying is exactly where salsa macha gets its soul. The árbol, laddered to IFI-H 300, gives a warmth you can spoon freely; the ancho carries the raisined bass underneath.

IFI PROFILE



IFI-H	300
IFI-P	105
IFI-C	150
IFI-U	700
IFI-S	600
IFI-B	2,000
IFI-K	1,300
IFI-A	500

Chapter 6 · Smoke — *chipotle, and the honesty of fire.*

A chipotle is a jalapeño that met a fire slowly. The chile is left on the plant to ripen from green all the way to red — most jalapeños are picked green, so a red jalapeño is already an act of patience — and then given days in wood smoke until it is mahogany, dense, wrinkled, and smells like a cabin in autumn. The two great forms are the **chipotle meco**, tan and leathery and intensely smoky, and the **morita**, darker and fruitier and more common north of the border. Both are the same transformation: fruit, time, and smoke.

We want to be precise and a little humble about what smoke is, because it marks the boundary of what the Index can and cannot touch. Smoke is aroma and process — several hundred volatile phenols (guaiacol, syringol, and their kin), carbonyls, and furans laid onto the surface of the fruit by the incomplete combustion of wood, then driven into the flesh as it dries. It is read mostly by the nose, not the tongue, and it corresponds to no single receptor on the Index. There is no IFI axis for smoke, and we do not pretend to engineer one. The smoke is the smoker's art — the choice of wood, the temperature, the days — and we leave it exactly there, with respect.

Still, it is worth knowing what the smoke actually is, because the knowing shapes how you cook with it. Smoke is wood taken apart by heat. The lignin that stiffens the wood pyrolyzes into the aromatic phenols — guaiacol, which is the very smell the word "smoky" points at, and syringol, which carries much of smoke's pungent edge — while the cellulose and hemicellulose break down into carbonyls and furans that brown the surface and deepen the color. Temperature decides the character: a cool, slow smoke (the *chipotle meco* way) lays down aroma while the chile dries gently, giving the leathery, tan, intensely smoky pod; a warmer, quicker smoke chars more and ripens the fruitier, darker *morita*. None of it is a taste in the tongue's sense — it is almost entirely retronasal, read by the olfactory bulb as the aroma climbs from the back of the mouth to the nose — which is precisely why no IFI axis claims it. The Index is a map of the tongue's receptors; smoke is the nose's country, and we do not survey land we cannot measure. We only make sure the chile beneath the smoke arrives at a known heat, so the smoker's art has steady ground to build on.

There is a reason the jalapeño, of all chiles, became *the* smoked chile, and it is pure practicality turned into art. A ripe jalapeño is thick-fleshed and high in moisture — too fat and too wet to air-dry on a string the way a thin-walled guajillo or árbol will. Leave it in the open and it rots before it cures. Smoke solves both problems at once: the gentle heat drives the water out while the smoke's phenols lay down both flavor and a measure of antimicrobial protection, saving a fruit that would otherwise be lost. People were smoking chiles this way long before refrigeration gave anyone a choice — the word itself is Nahuatl, *chīlpoctli*, "smoked chile," worn down over centuries into *chipotle*. The chile is, in other words, a preservation

technology that happened to taste extraordinary, which is the same sentence you could write about nixtamal, about drying, about the pickle: this cuisine's deepest flavors are very nearly all the delicious residue of keeping food alive through a season.



The controlled chamber, where the one thing we can fix is fixed: the chile's heat, held to a number before it ever meets the fire.

What we *can* do is tune the chile underneath the smoke, and here the engineering earns its keep in a way a cook feels immediately. A traditional chipotle lands near IFI-H 180 — but that is an average of a gamble. It began as a jalapeño, and field jalapeños swing wildly in heat from plant to plant and season to season; the smoking only fixes the aroma, not the fire. So a chipotle salsa made from last year's crop and this year's can burn at noticeably different levels through no fault of the cook, which is precisely why scaling a chipotle product is a nightmare. Fix the fruit's IFI-H to a chosen value *before* it ever reaches the smoker — the same ≤7% CV we hold across the whole platform — and the smoke lays onto a known quantity. The warmth is identical every batch; the smoke is now free to be the one glorious variable it deserves to be. We hold the bitterness down a little as well, because smoke and a hard char are both bitter signals, and a chipotle should always read as leather and depth, never as ash. The fire stays the cook's. The chile arrives ready for it.

Chipotles en Adobo

Makes about 2 cups · 45 minutes · the pantry jar that improves everything it touches

The canned chipotle in a dark, tangy, tomato-and-chile sauce is one of the great convenience ingredients of any cuisine — a spoonful lifts a pot of beans, a braise, a mayonnaise. Made from scratch it is far better, and it keeps for weeks.

You need

```
12          dried chipotles (meco or morita), stemmed
4           guajillo chiles, stemmed and seeded
3           ripe Caldera tomatoes (or best umami-restored tomato)
1/2         white onion · 4 cloves garlic
3  tbsp      cider vinegar · 1 tbsp piloncillo or brown sugar
1  tsp       cumin · 1 tsp Mexican oregano · 2 bay leaves · salt
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Make it

1. Rinse the chipotles and guajillos; toast the guajillos a few seconds on a dry comal. Cover all the chiles with hot water and soak 20 minutes.
2. Char the tomatoes, onion, and garlic on the comal until blackened in patches. Blend half the soaked chiles with the charred vegetables, vinegar, sugar, spices, and a cup of the soaking water until smooth.
3. Simmer the sauce with the bay leaves and the whole remaining chipotles, 20–25 minutes, until thick and glossy. Salt to taste. The whole chiles plump in the sauce and come out silky.

Why it works — The chipotles arrive pre-fixed at IFI-H 180, so the jar you make in January and the jar you make in July carry the same warmth — the variable that always sabotaged a chipotle at scale, held. The Caldera tomato brings IFI-U 2,600 of restored savory depth so the sauce reads rich rather than merely sharp, and with the chiles' bitterness tuned down the char from the comal reads as smoke-on-smoke, never as ash.

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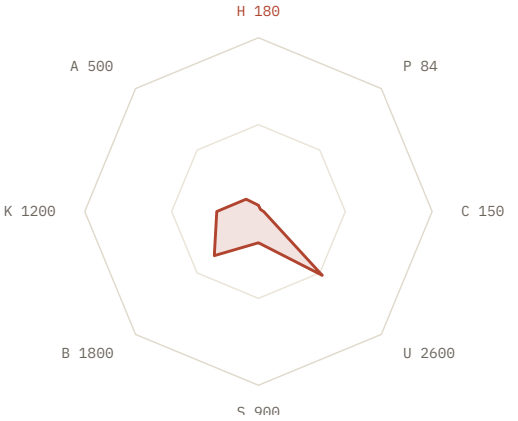


IFI-H	180
IFI-P	84
IFI-C	150
IFI-U	2,600
IFI-S	900
IFI-B	1,800
IFI-K	1,200
IFI-A	500

Chapter 7 · Adobo — *the marinade that remembers.*

Before refrigeration, *adobo* was a way to keep food alive a little longer — a paste of dried chiles, garlic, vinegar, and spice whose acid and salt held spoilage at bay while they seasoned. What it became, once it no longer had to preserve anything, is something better: the marinade that gives a cuisine its memory. It is the red-brown coat on everything from a Sunday's meat to a weeknight's mushrooms, the flavor a whole country recognizes with its eyes closed. It is mostly guajillo and ancho — bright tannic berry over dark raisin — rounded with garlic, lifted with cumin and Mexican oregano, cut with vinegar. The heat is almost beside the point. Adobo is about depth, and depth is exactly where our quieter axes do their work.



Garlic, grown for body: the kokumi that an adobo used to need hours of simmering to find, written into the clove through the CaSR pathway.

The roundness of a great adobo — the sense that it has been cooking far longer than it has — is **kokumi**, and kokumi is the most invisible and most valuable axis in the Index. It is not a taste of its own; it is a modulation of the others, the quality of richness, continuity, and mouth-filling body that a dish gains from long cooking or long aging. Its receptor is **CaSR**, the calcium-sensing receptor, and its agonists are **γ-glutamyl peptides** — short chains like glutathione and γ-glutamyl-valyl-glycine that a plant accumulates slowly, or that form over hours in a stockpot. Garlic is naturally rich in them, which is why garlic is the backbone of savory

cooking the world over; garlic grown for kokumi carries more, so an adobo built on it has the long-cooked roundness in an hour that it used to need an afternoon to find.

The mechanism under that roundness is worth naming, because kokumi is the least-understood of the eight axes and the most quietly magical in the mouth. CaSR is not a taste receptor in the ordinary sense — it is the body's calcium sensor, found throughout the physiology — and the kokumi compounds work on it *allosterically*: they taste of almost nothing themselves, but they bind a site on the receptor that makes it more sensitive to everything else, so that salt reads saltier, savory reads deeper, and the whole sensation gains body and a long, continuous finish. The most potent of the natural agonists is a tiny tripeptide, γ-glutamyl-valyl-glycine, with glutathione and other γ-glutamyl peptides close behind — the very molecules that accumulate slowly in an aged cheese, a long-simmered stock, or a well-grown head of garlic. To grow garlic for kokumi is to grow more of them, which is how an engineered clove hands a one-hour adobo the body a stockpot spends a day building.

The word itself has travelled, and the travel is a small history of the dish. *Adobo* is Spanish, from *adobar*, to marinate or pickle; the colonizers brought the technique and the word, and the Americas answered with the chiles that made it their own. The same root sailed onward to the Philippines, where *adobo* became a vinegar-and-soy braise entirely unlike Mexico's — one word, two cuisines, each certain it owns the thing. Mexico's version kept the chile at its heart, which is exactly why, of all the world's adobos, it is the one that reads across the whole Index.

The Yucatán keeps its own branch of this family, and it is worth a glance because it shows the same idea in a different grammar. There the marinade is called a *recado* — a dense spice paste sold in bricks in every market — and the most famous, *recado rojo*, is built on achiote, its bixin staining everything the deep orange-red of *cochinita pibil*; the rarer *recado negro* is built on chiles burnt deliberately to charcoal black, a sauce that is almost pure controlled bitterness, walking the TAS2R38 edge even more daringly than a mole. Adobo, recado, *adobar*, *recaudo* — the words shift from region to region, but the act is one act: a chile-and-spice paste that carries a dish's whole memory, and that the Index can now read in whichever dialect names it. Over the top of that body, Mexican oregano brings its sharp herbal lift on **IFI-P** — pungency through **TRPA1**, the same fast channel the fresh chiles fire — and the dried chiles, toasted for their fruit, keep their bitterness tuned down so the paste tastes of berry and earth, never of scorch.

A word, here, about who this marinade is for. Adobo loves pork and it loves a king oyster mushroom exactly as much, and we make no distinction between them and offer no apology for either. This is a plant-reverent kitchen and a vegetarian-first one by default — most of what we cook, and most of what the milpa grew, needs no animal to be whole — and the adobo on a slab of roasted squash is not a substitute for anything. It is the dish. When the same paste goes on

pork, it goes on with the same respect. The marinade does not know or care what it is coating; it was built to give memory, and it gives it generously to whatever you bring it.

Adobo Rojo

Makes about 1 cup · 25 minutes · for anything you want to taste like Sunday

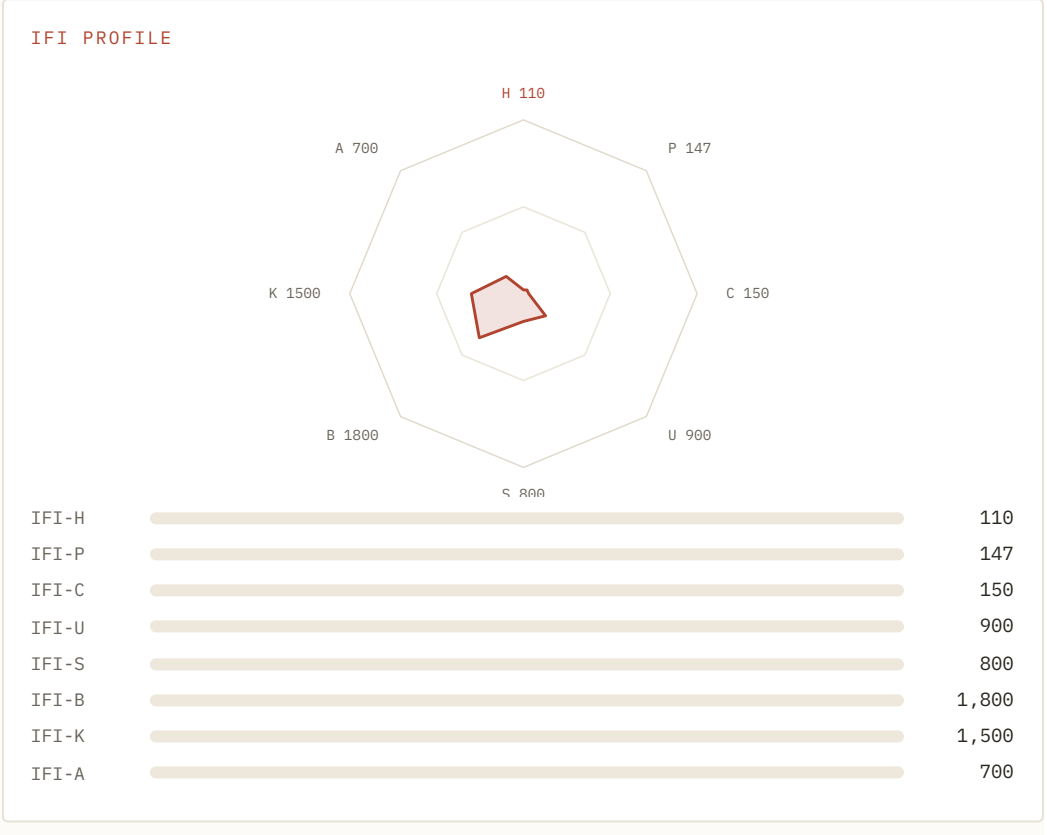
You need

4		guajillo chiles, stemmed and seeded
2		ancho chiles, stemmed and seeded
4	cloves	garlic
1	tsp	cumin seed, toasted
1	tsp	Mexican oregano
2	tbsp	cider vinegar
		sea salt · a little chile-soaking water

Make it

1. Toast the guajillo and ancho on a dry comal just until fragrant — seconds, not minutes. Cover with hot water and soak 15 minutes until supple.
2. Toast the cumin until it smells like a spice market; grind it with the oregano.
3. Blend the soaked chiles with the garlic, spices, vinegar, salt, and just enough soaking water to make a thick, clinging paste.
4. Coat whatever you are cooking and give it at least an hour — overnight is better. The paste goes on raw and cooks into a lacquer.

Why it works — The chiles sit low on the ladder, near IFI-H 110, so adobo can coat a whole roast or a tray of mushrooms without overwhelming it. The depth you taste is grown, not boiled in: garlic tuned for kokumi (IFI-K 1,500) delivers the long-cooked roundness in an hour, and with the dried chiles' bitterness held down the toasted paste reads as pure fruit and earth. The cumin and oregano ride over the top on IFI-P, the bright herbal line that keeps a dark marinade from going heavy.





PART III OF V

Los Frescos · The Fresh Chiles

the green and the grassy · TRPA1 and the bright top note · the fruited inferno

Chapter 8 · The Fresh Chiles — *green, bright, and quick.*

Where the dried chiles are patient, the fresh ones are immediate — jalapeño, serrano, poblano, güero, cut raw into a bowl or blistered on a comal until the skins go to leopard. Their heat is a different creature from the dried: higher on the ladder, greener in character, quicker to arrive and quicker to leave. And it carries a brightness that is pure pleasure and pure summer — a grassy, vegetal, almost cut-stem quality that has nothing to do with heat at all.

That brightness is worth naming precisely, because it is a second axis hiding inside what most people call "spiciness." Much of the lift of a fresh chile is not IFI-H but **IFI-P** — pungency, read through **TRPA1**, a channel kin to TRPV1 but faster and sharper, the same receptor that answers to raw garlic's allicin, to mustard and wasabi, to the sting of a cut onion. TRPA1 flashes where TRPV1 lingers: it is the quick top note, the sharp inhale at the front of a bite, gone before the deeper warmth even arrives. The *green* of a fresh chile, meanwhile — that grassy, bell-pepper, cut-grass aroma — is largely one remarkable molecule, **2-isobutyl-3-methoxypyrazine**, which the nose can detect at a few parts per *trillion*. When you taste a jalapeño as "bright and grassy and hot," you are reading three separate channels at once — a pyrazine on the nose, TRPA1 at the front, TRPV1 behind — and the Index lets us finally pull them apart.

Ripeness moves all three of those channels at once, which is why a red jalapeño and a green one are, honestly, different ingredients. A chile ripens from green to red as chlorophyll breaks down and carotenoids build up, and across that same window the capsaicinoids climb to a peak and then plateau, while the sharp green pyrazine fades and sweeter, fruitier notes come forward. A green jalapeño is the fruit caught early — grassy, bright, its heat still rising; the red is the fruit at rest — rounder, sweeter, often a shade hotter. The cuisine uses both on purpose, and heat laddering lets a grower hold a chosen point on that ripening curve steady instead of gambling on the day of the harvest.

The two heat channels differ in *tempo*, and the tongue reads that difference as character. TRPA1, the pungency channel, is the sprinter — fast to open, fast to fade — so its signal is the sharp inhale at the very front of a bite, the thing a raw serrano or a scrap of raw onion delivers before anything else arrives. TRPV1, the heat channel, is the distance runner — slower to rise, far slower to release — so its signal is the warmth that lands a beat later and lingers after the plate is cleared. A fresh chile fires both, which is why its heat seems to have an attack and a tail; the Index scores them on separate axes, IFI-P and IFI-H, precisely because they are two different runners, and a cook may well want to tune one without the other.



The fresh chile, whole and green: the pyrazine brightness and the TRPA1 top note are the sound of the fruit being fresh, and no number improves them.

For the fresh chiles we mostly stay out of the way, and knowing *why* is the point. A poblano for *rajas* wants its mild, meaty IFI-H near 55 and its green bite entirely intact; a serrano for a table salsa wants its clean 330 and nothing softened; the brightness is the fruit announcing that it was alive this morning, and nothing we could do to it would be an improvement. Where we reach in, it is almost always for consistency rather than change — a serrano crop that holds its heat to ≤7% so a restaurant's salsa verde tastes the same in June and in December, a poblano whose heat we fix so a chile relleno is never an unpleasant surprise for a child. And now and then, for a cook who wants it, a poblano that keeps every molecule of its character with its heat set to a beginner's first comfortable step onto the ladder — because the whole promise of reading Pun1 as a dial is that we can move the heat without touching the green. The brightness we never touch. It is the chile being fresh, and the Index's job there is only to measure it, not to meddle.

It is also worth naming what the poblano becomes when a cook decides to show it off, because those dishes are the chile's own argument for consistency, made delicious. Stuffed with cheese, battered, and fried, it is the *chile relleno* — a dish in which a single unexpectedly hot poblano can ambush a whole plate. Stuffed with a sweet-savory *picadillo*, cloaked in walnut cream, and scattered with pomegranate, it is *chiles en nogada*, the green-white-red showpiece of the Mexican table, where the poblano's heat must sit low and gentle beneath the sweetness or the whole composition tips. Both are exactly where a fixed, predictable poblano earns its keep — not to make the chile other than it is, but to be sure the one in the middle of the tray is the same as all the rest. (Its pale cousins, the waxy yellow *güero* chiles, ask the same of a cook and answer to the same dial.)

Rajas con Crema

Serves 4 as a filling or a side · 25 minutes · the poblano at its gentlest and best

Rajas — "strips" — is the poblano's home dish: the chile charred, peeled, and cut into ribbons, then stewed soft with onion and cream until it is one of the most comforting things in the cuisine. It is meatless by nature and wants nothing added. It is also the clearest argument for heat laddering, because the poblano's one flaw is

unpredictability: most are gentle, but every few chiles there is a hot one, and in a creamy dish meant for the whole table that surprise is unwelcome.

You need

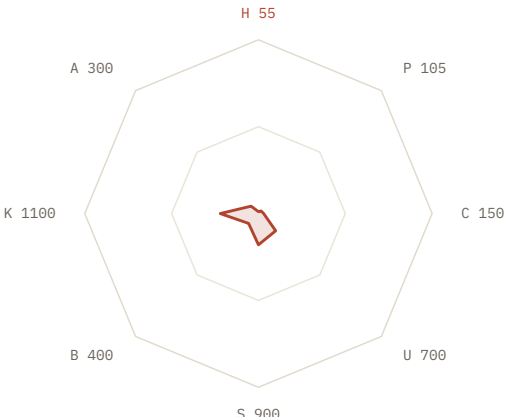
6	poblano chiles
1	large white onion, sliced
2 tbsp	butter or oil
1 cup	Mexican crema (or crème fraîche)
1/2 cup	corn kernels (optional, and lovely)
	salt · a little crumbled queso fresco to finish

Make it

1. Char the poblanos directly over a flame or under a broiler until the skins blacken all over. Sweat them in a covered bowl 10 minutes, then rub off the skins, stem and seed them, and cut into ribbons.
2. Cook the onion slowly in the butter until soft and sweet, 10 minutes. Add the corn and the poblano strips; warm through.
3. Lower the heat, stir in the crema, and let it barely simmer until it coats — 3 or 4 minutes, no more, or it will split. Salt, and finish with queso fresco.

Why it works — Built on a poblano fixed at IFI-H 55, every chile in the pan carries the same gentle warmth, so the dish is reliably soothing rather than a lottery — the heat laddered down to where cream wants it while the poblano's green, blistered character (IFI-P 500) stays exactly intact. The corn's own sweetness and the crema's fat round the whole thing into comfort.

IFI PROFILE



IFI-H	55
IFI-P	105
IFI-C	150
IFI-U	700
IFI-S	900
IFI-B	400
IFI-K	1,100
IFI-A	300

Chapter 9 · Habanero & the Yucatán — *the fruited inferno.*

The habanero is a different species from most of the canon — *Capsicum chinense*, the lantern-shaped chile the Yucatán made its own — and it is the proof that heat and beauty are not opposites but partners. Behind its fire is a wall of fruit and flowers: apricot, citrus, something almost tropical and perfumed, the gift of a rich set of volatile esters the species carries that the workhorse *C. annuum* simply does not. That perfume is laid over a burn that *starts* near 100,000 Scoville — where most of the everyday canon tops out — and climbs from there.

That perfume is not a vague impression; it is a readable chemical signature. Where *C. annuum* leans on green pyrazines, *C. chinense* pours out volatile **esters** — compounds the gas chromatograph resolves into the hexyl, methyl, and ethyl esters the nose reads as apricot, pear, and tropical flower — layered over terpenes that add citrus and resin. It is the same ester-forward chemistry that makes the Scotch bonnet of the Caribbean and the ají of the Andes smell of fruit while they burn; this species carries its perfume the way the workhorse species simply cannot. Genetically it is a separate domestication with its own center of diversity in the lowland Amazon, carried north into the Yucatán and adopted so completely that the Spanish, first meeting it in the Caribbean, mislabeled it *chinense* — "from China" — one of botany's famous wrong guesses, now permanent. The point for us is that a species already built to carry fruit alongside fire is the right chassis for a full-spectrum chile: when we ask a plant to express sweetness and umami and kokumi on top of heat, it helps enormously to begin with one whose whole nature was always to layer. The Yucatán built an entire regional cuisine on the tension between that fruit and that fire, most purely in a raw salsa that is almost nothing but the two of them held against each other.



Phoenix, the full-spectrum flagship: ⋆C. chinense⋆ carried gene by gene to the top of the world, and still, underneath the fire, a habanero's fruit.

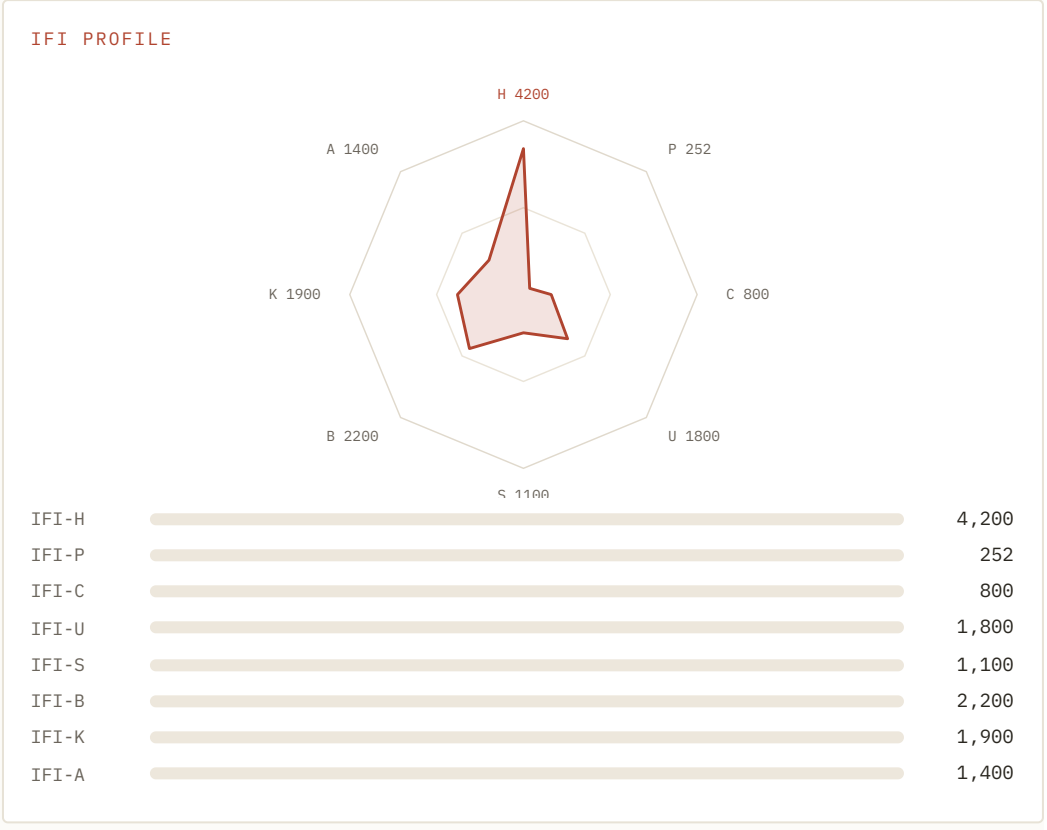
This species is where our own work lives, and it is no accident. *C. chinense* is where the heights of heat are reachable, and its fruit gives an engineered burn somewhere gorgeous to stand — a fire with a view. Our ten proof-of-concept superhots are all this lineage,

a ladder climbing from Ember at our model's predicted ~866,000 SHU to **Phoenix** at nearly three million (predicted), each rung scored on IFI-H and each one expressing a widening computational design scope and axis activation as it climbs. The top rung carries all eight at once — the only full-spectrum chile in existence — because the whole point of the flagship was to prove that a single plant, read and written at the level of its genes, could be made to speak every axis of the Index simultaneously.

CULTIVAR	SKU	PREDICTED SHU†	IFI-H	AXES
Ember	SS-0087	866K	1,570	2/8
Cinder	SS-0088	1.05M	2,290	3/8
Kindle	SS-0089	1.25M	2,000	3/8
Flare	SS-0090	1.48M	—	4/8
Blaze	SS-0091	1.72M	2,630	4/8
Wildfire	SS-0092	1.96M	2,930	5/8
Scorch	SS-0093	2.21M	3,220	5/8
Firestorm	SS-0094	2.47M	3,490	6/8
Solara	SS-0095	2.72M	3,980	6/8
Phoenix	SS-0096	2.95M	4,200	**8/8**

† All cultivar SHU values in this table are computational predictions from our flux model, not certified measurements.

Phoenix is the plant we built gene by gene, with the two AI-designed Pun1 edits of Chapter 4 — **S39L · L345G** — because the chile that could reach that number did not yet exist in nature and was not going to arrive by waiting. Read its full profile and you can see the whole Index expressed in one fruit: a towering heat, yes, but also real sweetness, real umami, a tuned-down bitterness, a kokumi body, a tannic astringent finish.



Phoenix · SS-0096 · the full-spectrum flagship — every axis of the Index alive in a single Capsicum chinense fruit.

And yet almost no Yucatán cooking needs the top of that ladder — which is exactly the point of having read it. Knowing precisely how far the fire can go is what lets you place a table sauce with

confidence near the *bottom*, where the fruit does the talking and the heat is a true, generous warmth rather than a feat of endurance. The ladder is not built so that every dish climbs it. It is built so that you can choose your rung on purpose.

Salsa de Chile Habanero — Xni-Pec

Makes a small bowl · 10 minutes · "dog's nose," for the sweat it raises

The Yucatán's great raw salsa is almost nothing — habanero, onion, the juice of a bitter orange, a little cilantro — and it lives entirely on the tension between fruit and fire. We build it on **Ember**, the gentlest rung of the ladder, so the heat is real and the fruit is loud, and we hold the chile's bitter edge down so the raw sauce stays bright to the last spoonful.

You need

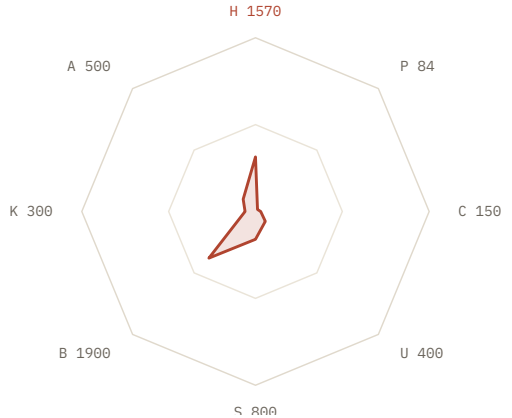
2		ripe habaneros (Ember, if you want the ladder honest), minced
1/2		white onion, minced fine
		juice of 2 sour oranges (or 1 orange + 1 lime)
1	small	handful cilantro, chopped
		sea salt

Make it

1. Combine the onion and citrus juice in a bowl and let it sit 5 minutes — the acid softens the onion's raw edge and turns it faintly sweet.
2. Mince the habaneros as fine as your patience allows; add them with their seeds for the full climb, without for a gentler one. (The heat is in the ribs the seeds press against, not the seeds themselves — but seeding is the easiest way to pull ribs and all.)
3. Fold in the cilantro and a good pinch of salt. Rest 10 minutes before serving, so the fruit of the chile blooms into the juice.

Why it works — Ember carries IFI-H 1,570, a true heat and the first rung of our ladder, but its fruit runs ahead of the fire, and with the chile's bitterness tuned down the raw sauce never turns hard. The sour orange is not fighting the heat; it is lighting the fruit the heat is standing on. This is the whole Yucatán idea in one bowl — fire as the frame, fruit as the picture.

IFI PROFILE



IFI-H	1,570
IFI-P	84
IFI-C	150
IFI-U	400
IFI-S	800
IFI-B	1,900
IFI-K	300
IFI-A	500



PART IV OF V

The Sauces · Daily and Grand

roja and verde · the swicy ratio · the cathedral of mole · the live pickle

Chapter 10 · The Salsas — *the daily sauce, scored.*

A Mexican table is not dressed by one sauce but chooses between two every day: the red and the green. *Roja* is the cooked, deep, charred tomato-and-dried-chile sauce; *verde* is the raw-edged, tart, tomatillo-and-fresh-chile one. Between them they cover nearly everything a plate can want — the roja for richness and the verde for lift — and both are built in minutes with nothing but a comal and a blender. The technique that defines the red is *tatemado*, the deliberate charring of vegetables on a dry griddle until they blacken in patches and go soft and sweet inside. It is roasting pushed right up to the edge of burning, and like the toasting of dried chiles it is a bitterness problem wearing a flavor's clothes: the char is where the smoky depth comes from *and* where the bitter TAS2R38 signal is born, in the same scorched skin. The whole art of a salsa roja is to toast brave enough for the depth and stop short of the harshness — and that edge is exactly what the Index lets us move.

Two tools make the *tatemado* what it is, and both are worth keeping even in a modern kitchen. The char itself is Maillard browning pushed to its limit — the same reaction that darkens a bread crust and sears meat, reducing sugars and amino acids recombining under dry heat into hundreds of new roasted, savory, faintly bitter compounds — run right up to the line where flavor tips into carbon. And the *molcajete*, the three-legged bowl of volcanic basalt, does something a blender cannot: its rough, porous stone tears the vegetables rather than slicing them, bursting cells and dragging out pectin so the sauce emulsifies into a thicker, coarser, more clinging thing. A molcajete salsa and a blender salsa of identical ingredients are different sauces in the mouth — the first lithic and rough, the second smooth and aerated — which is why so many cooks keep the stone for the sauces that matter. The Index does not touch texture; that stays entirely the cook's. What it fixes is the one variable the char always threatened — the bitterness born in the blacken — held down so the comal can be worked with a brave hand.

The red and the green are not quite the whole alphabet; there is a raw third that belongs beside them. *Pico de gallo* — *salsa fresca* — is uncooked and unblended, just tomato, onion, chile, and cilantro cut by hand and bound with lime and salt, all texture and brightness where the roja is depth and the verde is tartness. Between the three, a Mexican table holds a grammar of condiment as expressive as any set of sauces in the world: something deep, something sharp, something fresh, each a different axis brought forward, each spooned on to tune the plate in the diner's own hand. It is worth seeing the salsas this way — not as recipes but as a *system of adjustment*, the eater's own dial over heat and brightness and depth. The Index simply makes each dial's setting a number, so that the brand bottling the roja and the cook making the pico are, at last, speaking one measured language.



The tomatillo, husked: the green tartness and the faint tannic grip that make the verde a different sauce from its cooked red twin.

Salsa Roja de Molcajete

Makes about 2 cups · 20 minutes · the everyday red

The soul of a salsa roja is char, and the risk of char is bitterness. We build this on an umami-restored tomato and a chile de árbol laddered down to a sociable warmth, with the bitter signal tuned low so you can toast everything brave.

You need

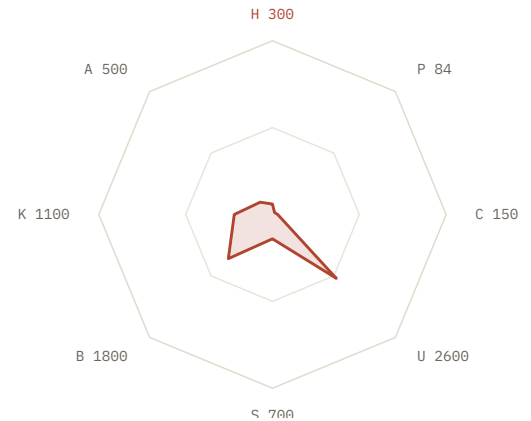
4	ripe Caldera tomatoes (or the best umami-restored tomato you have)
6	dried chiles de árbol, stemmed
3 cloves	garlic, unpeeled
1/4	white onion
	sea salt · a splash of warm water

Make it

1. Heat a dry comal or heavy pan until it just smokes. Char the tomatoes, garlic, and onion, turning, until blackened in patches and soft — 10 minutes or so. Slip the garlic from its skins.
2. In the last 30 seconds, toast the árbol chiles until they darken and smell nutty. Do not let them go to true black.
3. Grind or blend everything with a good pinch of salt and a splash of water to a coarse, pourable sauce. Taste; it should be smoky, deep, and only *then* hot.

Why it works — The Caldera carries IFI-U 2,600, roughly three times the free glutamate of a supermarket tomato, restored through the plant's own **mGluR1** pathway rather than added at the pot — so the char reads as savory depth, not scorch. The árbol, laddered to IFI-H 300, gives a warmth you can eat a whole bowl of, and with bitterness held down the blackened skins read as smoke instead of ash.

IFI PROFILE



IFI-H		300
IFI-P		84
IFI-C		150
IFI-U		2,600
IFI-S		700
IFI-B		1,800
IFI-K		1,100
IFI-A		500

Salsa Verde Cruda

Makes about 2 cups · 10 minutes · the bright, raw green

Where roja is cooked and deep, verde is raw and alive — tomatillos for their green tartness, serrano for a clean high heat, cilantro and onion for lift. The tomatillo we love here is still on our road ahead: *Tomatillo* **Acid** sits in the frontier tier of the Beyond-Peppers roadmap, a husk-fruit engineered toward a brighter, more reliable sourness. Until it arrives we build this on the best real tomatillos we can find and a serrano held to its honest heat.

You need

8		tomatillos, husked and rinsed
2		serrano chiles, stemmed
2	cloves	garlic
1/2		white onion
1	large	handful cilantro
		sea salt

Make it

1. For a raw salsa, blend everything from cold — tomatillos, serranos, garlic, onion, cilantro, salt — to a loose green sauce. For a rounder one, simmer the tomatillos and serranos 5 minutes first, then blend.
2. Rest 10 minutes and taste for salt and acid. It should be tart first, green second, hot third.

Why it works — The serrano holds IFI-H 330 — a clean, high heat that arrives fast and leaves faster — and much of what you read as *brightness* is actually **IFI-P**, pungency through the **TRPA1** channel, the sharp top note the raw onion and chile fire together. The sourness and the faint green grip are the tomatillo's own — that grip is **IFI-A**, astringency, the tannin-like pull the salivary proline-rich

proteins register. The day a husk-fruit is tuned to deliver its sourness on cue, this sauce stops being a gamble on the market and becomes a number.

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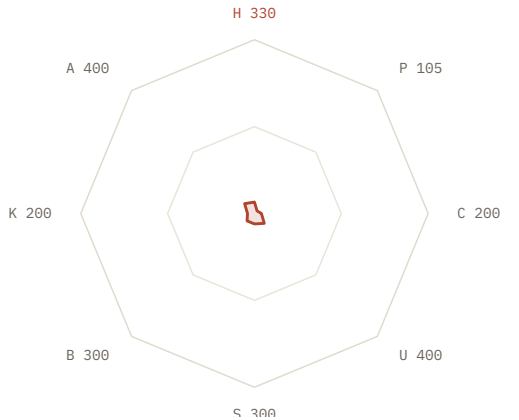


IFI-H	330
IFI-P	105
IFI-C	200
IFI-U	400
IFI-S	300
IFI-B	300
IFI-K	200
IFI-A	400

Chapter 11 · Al Pastor & the Sweet Side — *heat that tastes like fruit.*

This cuisine understood, centuries before the rest of the world gave it a name, the thing now trending as *swicy*: heat and sweetness as partners rather than opposites. It is everywhere once you look — mango with chile and lime from a street cart, tamarind candy that burns, watermelon dusted with árbol powder, *chamoy*. And it reaches its glory in *al pastor*: chile-and-achiote-marinated pork stacked on a vertical spit — the *trompo* — with a whole pineapple crowning the top, its juices basting down through the meat as it turns and chars. The technique came from Lebanese immigrants and their shawarma spit; Mexico made it so completely its own that it is now unthinkable as anything but Mexican. And it is, at heart, an IFI composition problem written in fruit.

Heat and sweetness are a genuine design tension, not a metaphor. Capsaicin at **TRPV1** and sugars at the **TAS1R2·TAS1R3** pair are read by the brain as near-opposites — sweetness is the ancient signal for *safe, caloric, good*, and heat is the signal for *danger* — and a clumsy combination simply has them cancel, each muting the other into a muddy, confused middle. The trick the street cooks found by instinct is that there is a *ratio* at which they stop cancelling and start amplifying: enough sweetness to round the fire's hard edge and make it read as lush, without so much that it smothers the burn into candy. Finding that ratio by taste takes a lifetime. The platform's **flux-balance model** finds it directly — it solves for the sweetness that balances a given heat the way it solves for any other constraint — which is the whole engineering idea behind the **M2 dual-axis library**, 8,400 constructs built specifically to hold two axes in deliberate proportion. An engineered al pastor marinade tastes *intended* rather than muddled because the proportion was computed, not guessed.

The reason the proportion has to be *found* rather than simply maximized lies in how the brain assembles a flavor. Sweetness and heat are not merely two signals that add; they are integrated centrally, in part as opponents, so that past a certain point more sweetness genuinely *suppresses* the perceived burn and more burn flattens the perceived sweetness — each one buying the other down. There is a narrow band where, instead of cancelling, they lift: the sweetness rounding the fire's hard leading edge into something lush while leaving its warmth intact. That band is what the dual-axis work targets — the **M2 library**, 8,400 constructs built specifically to hold two axes in a chosen ratio rather than drive either to its ceiling. It is a different engineering goal from the superhot ladder: not *how loud can one axis go* but *how do two axes sit together without fighting*. Nearly every great composed dish in this book is quietly solving that second problem, and al pastor is simply its most delicious statement — fruit and fire on one spit, turned until they agree.



A superhot in cross-section: heat and sweetness live in the same fruit, and the flux-balance model finds the ratio at which they amplify instead of cancel.

There is a second, quieter piece of chemistry on the trompo worth naming, because it is the reason the pineapple belongs there and is not just decoration. Pineapple carries **bromelain**, a protease — a protein-cutting enzyme — and as its juice runs down the spit it gently tenderizes the surface of the meat even as its sugars caramelize into the char. The fruit is seasoning and marinade and basting liquid all at once. On a vegetarian trompo — and roasted squash or halved king oyster mushrooms take this marinade beautifully — you lose the bromelain's work on muscle but keep everything that matters to the flavor: the sweet char, the achiote's earth, the balanced fire.

The trompo's story is one of the great immigrant gifts to Mexican food, and it is worth telling because it shows the cuisine doing exactly what it has always done: adopting a word and making it a sentence of its own. In the early twentieth century, Lebanese immigrants settled in Puebla and across Mexico, bringing the vertical spit and the spiced, stacked lamb of *shawarma*. The first Mexican version was *tacos árabes* — the Levantine spit nearly intact, served on a pita-like flatbread. Then the next generation made it Mexican in every particular: the lamb became pork, the spit's seasoning became chile-and-achiote *adobo*, a pineapple was set to crown the trompo, and the flatbread became the corn tortilla. *Al pastor* — "shepherd style," a quiet nod to the lamb it descends from — is now so wholly Mexican that its foreign birth surprises people. It is the swicy problem solved not in a lab but on a street corner, by cooks balancing fruit against fire on a borrowed machine until the balance was theirs.

Adobo al Pastor

Makes enough for a generous platter · 20 minutes plus marinating · built for pork, and just as good on roasted squash or king oyster mushrooms

You need

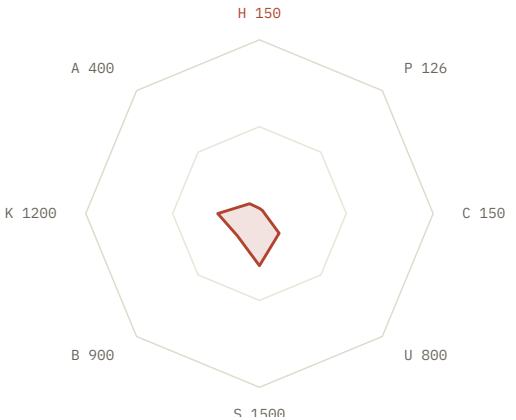
3		guajillo chiles, stemmed and seeded
2		ancho chiles, stemmed and seeded
2	tbsp	achiote (annatto) paste
1	cup	fresh pineapple, plus thick rings to grill
3	cloves	garlic
2	tbsp	cider vinegar
1	tsp	cumin · 1 tsp Mexican oregano · sea salt

Make it

1. Toast and soak the chiles as for adobo. Blend with the achiote, pineapple, garlic, vinegar, spices, and salt to a smooth, sunset-colored paste.
2. Coat the pork — or thick slabs of squash, or halved king oyster mushrooms — and marinate at least 2 hours, ideally overnight.
3. Sear hard, grilling pineapple rings alongside until caramelized. Chop everything together so the sweet char of the fruit runs through each bite. Serve on warm tortillas with onion and cilantro.

Why it works — The sweetness is held in deliberate balance against the heat: pineapple lifted toward IFI-S 1,500, guajillo kept low at IFI-H 150, so the fire reads as *fruit arriving warm* rather than a wall, and then finishes clean. The achiote (bixin, a carotenoid from annatto seed) brings its earthy color and a grounding kokumi body. This is heat × sweetness composed on purpose — the oldest trick on this continent, finally given a ratio.

IFI PROFILE



IFI-H	150
IFI-P	126
IFI-C	150
IFI-U	800
IFI-S	1,500
IFI-B	900
IFI-K	1,200
IFI-A	400

Chapter 12 · Mole — *the cathedral.*

If the salsas are the daily language, mole is the epic — a sauce of twenty or thirty ingredients, built in stages over the better part of a day, in which chiles, seeds, nuts, dried fruit, bread, spice, and a little chocolate are each toasted and ground separately and then married into something no single part predicts. It is the cuisine's cathedral, and it is almost the only dish in this book that touches nearly every axis of the Index at once. Read a great *mole poblano* on the Index and it comes back close to full-spectrum: a modest heat, a deep bittersweet body, a round kokumi mouthfeel, the bright sting of canela riding over the top, a tannic finish from the chocolate and the seeds. It is the most complete argument in the whole cuisine that flavor is not one thing but a chord.



Cacao, whole: native to these lands and sacred to them, on our horizon but not our work — the chocolate in this mole is real chocolate, and we would not have it otherwise.

Here we must be honest about one ingredient, because the honesty is part of the reverence. Cacao is native to Mesoamerica and sacred to it — *Theobroma*, "food of the gods," a currency and a ritual drink long before it was ever sweetened — and it is on our horizon, not in our hands. We have not engineered it. The chocolate in this mole is real chocolate, with all its tannin and all its bitterness intact, and we would not have it any other way. The design in this sauce lives entirely where our library already reaches: in the chiles held low and sweet, in the garlic grown for body, and above all in **IFI-B**, the bitterness we tune down across the whole dark assembly. Think

about what a mole actually is, chemically: a sauce built almost entirely from *browned* things — hard-toasted chile skins, seeds fried dark, bread burnt near black, scorched onion, and bitter chocolate on top of all of it. Every one of those is a TAS2R38 signal. A lesser cook's mole collapses into a single flat wall of bitter; a master's walks right up to that wall and never touches it, by balancing the bitterness against enough sweetness and fat and body that it reads as *depth*. Mole has always been a high-wire act over bitterness. The Index does not replace the master. It simply lowers the floor of the TAS2R38 signal so the walk is survivable for the rest of us — so a sauce can be toasted brave, the way a mole must be, and still arrive as bittersweet and glossy rather than acrid.

The canela over the top is the other axis to watch. True Ceylon cinnamon — *canela*, soft and crumbly, not the hard cassia sold as "cinnamon" in much of the world — carries **cinnamaldehyde**, and cinnamaldehyde is a **TRPA1** agonist. That is why a stick of canela in a mole reads as *bright* and not merely sweet: it is firing the same fast pungency channel as the fresh chiles and the Mexican oregano, laying a sharp warm line of **IFI-P** across the dark body underneath. A mole without that bright top note is a cellar with no window. With it, the whole cathedral has light coming in.

Oaxaca calls itself *la tierra de los siete moles*, the land of the seven moles, and the boast is the best argument there is that mole is not one sauce but a whole genre — a form, like the sonnet, within which endless individual sauces are composed. Each of the seven is a different balance of the same axes, and reading them side by side is reading the Index played as a scale.

MOLE	COLOR / CHARACTER	THE AXIS IT LEADS WITH
Negro	near-black; chilhuacle + burnt chile + chocolate	`Zero-Bitter (the darkest toast)`
Rojo	deep red; ancho + guajillo + nuts	`Kokumi (round body)`
Coloradito	brick-red; lighter, a touch sweet	`Sweet × Heat`
Amarillo	golden; chilhuacle amarillo + herbs	`Pungency (hoja santa)`
Verde	bright green; fresh herbs + pumpkin seed	`Pungency (raw, green)`
Chichilo	smoky; charred chile seeds; rare	`Zero-Bitter (char)`
Manchamanteles	fruit-laden; "tablecloth-stainer"	`Sweet (plantain, pineapple)`

The *negro* — the most famous and most laborious, and the one that reaches for the scarce Oaxacan chilhuacle of Chapter 1 — leans hardest on the darkest toast, its chiles and seeds taken nearly to black. Which is precisely why it most needs the bitterness held in check, and precisely where the Index earns its keep inside the cathedral.

Mole de la Casa, Short Form

Makes about 4 cups · 2 hours · a day's sauce, honestly done in an afternoon

A true *mole poblano* is a day's work and a family's inheritance, and nothing here replaces that. This is the honest short form — fewer ingredients, two hours, the architecture intact — for a weeknight that wants the cathedral.

You need

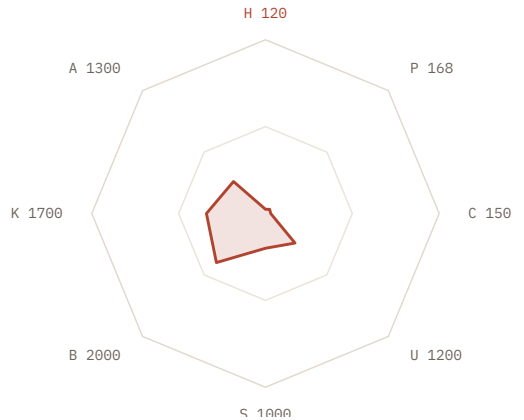
3		ancho chiles, stemmed and seeded
2		mulato chiles, stemmed and seeded
2		pasilla chiles, stemmed and seeded
2	tbsp	sesame seeds
2	tbsp	almonds
1/4		white onion
2	cloves	garlic
1		ripe plantain, or 2 tbsp raisins
1		(2-inch) stick canela (Ceylon cinnamon)
30	g	dark chocolate
3	cups	vegetable stock · sea salt

Make it

1. Toast each dried chile a few seconds a side on a dry comal; soak in hot water 20 minutes.
2. In the same pan, toast the sesame and almonds gold; set a little sesame aside to finish. Blister the onion and garlic. Soften the plantain or raisins.
3. Blend the soaked chiles, seeds, nuts, onion, garlic, fruit, and canela with enough stock to move the blades, to a smooth paste.
4. Fry the paste in a little oil over medium heat, stirring constantly, until it darkens and thickens — about 10 minutes. It will spit; keep it moving.
5. Loosen with the rest of the stock, drop in the chocolate, and simmer gently 30 to 40 minutes until glossy and deep. Salt to taste. Finish with the reserved sesame.

Why it works — Every component is a bitter signal, and a mole lives or dies on keeping them in concert. With the chiles' bitterness tuned to IFI-B 2,000 the whole dark assembly reads as bittersweet depth rather than harshness, which is what lets you fry the paste genuinely dark — where the flavor is — without the sauce turning on you. The garlic's kokumi (IFI-K 1,700) gives the body a mole usually needs far longer to build; the canela's cinnamaldehyde cuts a bright IFI-P line over the top; and the chocolate stays exactly itself, tannin, astringency, and all. The design simply makes room for it.

IFI PROFILE



IFI-H		120
IFI-P		168
IFI-C		150
IFI-U		1,200
IFI-S		1,000
IFI-B		2,000
IFI-K		1,700
IFI-A		1,300

A near-full-spectrum dish: seven axes alive at once, the bitterness held in check across the whole dark assembly, the body grown in, the chocolate left as it is.

Chapter 13 · Encurtidos — *the pickle, and the live culture.*

Not every chile in this cuisine is cooked or dried. A great many are *pickled* — the bright, acidic jalapeños and carrots and onions that sit on every taquería counter, the *cebollas encurtidas* stained pink with the juice of the chile, the escabeche that cuts the richness of everything it sits beside. Acidity is the fourth great preservation art of this kitchen, alongside drying, smoking, and the alkaline bath of nixtamal, and it does something to the perception of heat worth understanding before you reach for the vinegar.

Capsaicin is not destroyed by acid — it is a stable molecule, indifferent to a splash of vinegar — but the *experience* of heat shifts in an acidic matrix. A low pH sharpens and quickens the burn's attack, pushing it forward on the palate, while the astringency of the acid and the coolness of a chilled pickle give the whole sensation edges it would not otherwise have. A pickled serrano reads hotter and faster than the same serrano raw, not because it carries more capsaicin but because the acid changes how the signal arrives. For a cook laddering heat, that is a real variable: a chile destined for a pickle can be set a rung lower than one destined for a cooked sauce and still land in the same place on the tongue.



The petri dish: where a chile mash becomes a living ferment, and the number we fixed in the plant rides through the culture unchanged.

Beyond the quick vinegar pickle lies the deeper art of the *live* ferment — the lacto-fermentation that turns a simple mash of chiles and salt into the backbone of the world's great hot sauces. Submerge chopped chiles under a brine of the right salinity, keep oxygen out, and the native **lactic-acid bacteria** on the fruit's own skin — *Lactobacillus* and its relatives — go to work, consuming the sugars and dropping the pH as they produce lactic acid, until the mash is both preserved and transformed, its raw green sharpness mellowed into something round, funky, and complex. This is where designed flavor meets living culture, and the two turn out to be

natural allies. A fermenter's oldest frustration is inconsistency — every batch of wild chiles starts at a different heat, so every batch of sauce finishes at a different heat — and a cultivar whose IFI-H is fixed at ≤7% CV hands the fermenter a known starting point for the first time.

The ferment itself is a succession, and knowing its shape is half of controlling it. Submerge the chiles under a brine of the right strength — commonly two to five percent salt, enough to suppress spoilage organisms while the ones you want thrive — seal out the oxygen, and a relay race begins. The early sprint belongs to *Leuconostoc*, a heterofermentative bacterium that throws off carbon dioxide and a first drop in pH; as the acidity climbs it hands off to the more acid-tolerant *Lactobacillus*, homofermentative, which drives the pH down from a starting 6 toward 3.4 or below — the point at which the mash is both safely preserved and fully transformed, its raw green sharpness mellowed, its sugars spent into lactic acid, new funky and complex notes built where none were before. Every leg of that relay runs truer from a known start, and a chile whose heat is fixed gives the fermenter the one steady point the process never had. The acid has a long name and a longer road: *escabeche* descends through Spanish from the Persian *sikbāj*, a vinegar stew that crossed the whole medieval Islamic world and washed up, at last, as the pink pickled onion on a taquería counter.

Follow the live ferment past the pickle and it arrives at the hot sauce the whole world knows. The great aged sauces are fermented chile *mash* — chiles and salt, held under their own brine for weeks or months or, in the famous cases, years in wood — during which the lactic acid builds, the flavors round and deepen, and the raw fruit becomes something mellow, complex, and almost winey. The barrel adds its own slow oxidation and a whisper of tannin; time does the rest. For the sauce maker the chile's fixed heat is the gift that keeps giving across that long maturation: a mash that begins at a known IFI-H ages toward a predictable place, so the sauce drawn from the barrel is the sauce the recipe promised rather than a happy accident of that one year's harvest. Design at the plant and patience at the barrel turn out to be the two halves of a single craft. The culture does its slow work on a chile whose fire is already a number; the funk and the acid are the ferment's to give, the heat is the one thing that no longer drifts. (This is a thread the library pulls much further in its own volume, *Fermentation & Heat* — here it is enough to say that the number and the live culture were made for each other.)

Jalapeños en Escabeche

Makes a large jar · 20 minutes plus a day's rest · the taquería counter at home

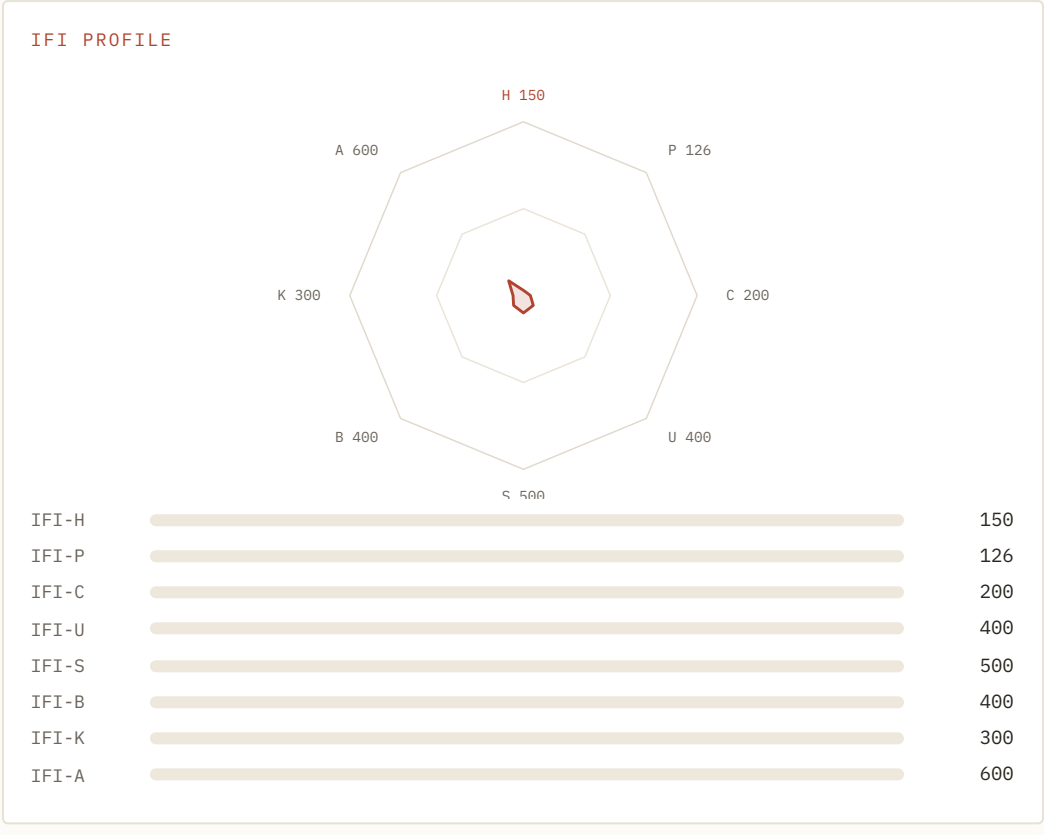
You need

```
10          jalapeños, sliced into rings (or left whole, slit)
2           carrots, sliced into coins
1           white onion, sliced
5  cloves   garlic, whole
1  cup       white vinegar · 1 cup water
1  tbsp      salt · 1 tsp sugar
1  tsp       cumin · 1 tsp Mexican oregano · 2 bay leaves · a few
peppercorns
```

Make it

1. Warm a little oil in a pan and sauté the garlic, onion, and carrots 3 or 4 minutes, just to start them.
2. Add the jalapeños, vinegar, water, salt, sugar, and all the spices. Bring to a simmer and cook 5 minutes — the carrots should stay with some bite.
3. Pack into a clean jar with the liquid, cool, and refrigerate. They are good in a day and better in a week.

Why it works — Built on a jalapeño fixed at IFI-H 150, the jar is reliably sociable rather than a gamble, and because the acid sharpens and quickens the burn's attack, that modest 150 arrives with real presence — heat laddered a rung lower than a cooked use would need, because the vinegar does part of the work. The cumin and oregano ride on IFI-P over the bright acidic cut.





PART V OF V

Foundations, Aromatics, and the Horizon

masa and the corn · the tomato restored · oregano, canela, vanilla · the number as a promise

Chapter 14 · Masa & the Corn Horizon — *the foundation, and the frontier.*

Underneath every chile in this book is corn. Not as a side but as the plate itself — the tortilla that carries the salsa, the tamal that holds the mole, the thick warm masa that every other flavor is served upon.

And masa is not one thing but a whole architecture of them. Pressed thin and griddled, it is the *tortilla*; wrapped around a filling and steamed in a husk, the *tamal*; pinched into a boat and crisped, the *sope* or the *huarache*; stuffed and folded, the *tlacoyo*; thinned to a drink, *atole* and *champurrado*; left whole as hominy, the body of a *pozole*. One dough, a dozen forms, each the plate for a different way of eating. And the maize beneath it is not one thing either: Mexico guards dozens of native landraces — scores of distinct corns bred over millennia into their local soils — in white and yellow and deep blue and red and black. The blue and red kernels carry anthocyanins, the same pigment class that tints a blueberry, and with them a faint astringency the Index reads on IFI-A: proof that even the plate has flavor worth measuring. To grow the staple well is to keep that diversity alive, which is its own kind of nourishment — of a cuisine, and of the ground it stands on.

The making of a tortilla is a small daily miracle of physics worth pausing on. A ball of fresh masa is pressed flat — between a cloth in a hinged press, or patted by hand — and laid on a comal hot enough to set the surface without drying it. There it is turned two or three times, and on the last turn, if the dough and the heat are right, it *puffs*: steam trapped between the two faces of the disk inflates it like a balloon, splitting it into the two thin layers that make a tortilla foldable and tender rather than a cracker. It is the cook's proof that the nixtamal was right — too dry and it will not puff, too wet and it tears — a piece of quality control performed a hundred times a day by hands that never needed the word "steam" to master it. The ≤7% CV we hold at the plant is only the same instinct, carried one step back up the chain to the seed. It is the humblest thing in the whole cuisine and the most important, and the alchemy that makes it possible is one of the great unsung technologies of human history.

Dried maize, eaten as it comes off the cob, is a poor food — its niacin is chemically bound and unavailable, its protein short on usable lysine, and a people who live on it untreated fall to pellagra, the deficiency disease that haunted every culture that borrowed corn from Mesoamerica without borrowing the *method*. The method is **nixtamalization**: simmering and then steeping the kernels in an alkaline solution of **cal** — calcium hydroxide, slaked lime — before grinding. What happens in that alkaline bath is a cascade of real and consequential chemistry. The outer pericarp of the kernel saponifies and slips away. The bound niacin is released into a form the body

can actually absorb, and pellagra simply never arrives. The balance of amino acids improves, raising the quality of the protein. Calcium crosses into the grain, so that a tortilla is a meaningful source of it. And the whole kernel takes on the aroma — that unmistakable toasty, faintly floral scent of fresh masa, carried by compounds like 2-aminoacetophenone — that says *tortilla* before you have taken a bite. The Mesoamericans worked this out millennia ago, by observation and inheritance, with no notion of niacin or saponification, and it is as elegant a piece of nutritional engineering as anything in a modern lab.

The cost of borrowing the grain without the method is written plainly in history. When maize left Mesoamerica for Europe, Africa, and the American South, the lime treatment largely did not travel with it — and wherever people came to live on unnixtamalized corn, **pellagra** followed: the deficiency disease of the "four Ds," dermatitis, diarrhea, dementia, and death, that scarred the American South deep into the twentieth century and killed in the hundreds of thousands before its cause in bound, unavailable niacin was understood. The people who had cooked corn the longest never suffered it, because they had never eaten corn the wrong way. It is the starkest argument imaginable that *how* a food is grown and prepared can matter as much as the food itself — the quiet thesis under this whole library, taught by the milpa five thousand years before anyone could name a vitamin.

The field itself was engineered too, in its way. The *milpa* interplants corn with beans and squash — the three sisters — and the arrangement is a closed agronomic and nutritional loop: the cornstalk gives the climbing bean its pole, the bean's root nodules host *Rhizobium* bacteria that fix nitrogen from the air and feed the hungry corn, and the broad squash leaves shade the soil and smother the weeds. Nutritionally the corn and the bean complete each other — the lysine the grain lacks, supplied by the legume — into whole protein. It is a designed system that needed no design on paper, only generations of attention, with the chile and the tomato growing right in among the sisters.



Corn, the foundation: the grain that an ancient alkaline alchemy made nourishing, and the frontier our own roadmap has not yet reached.

We dwell on nixtamal because it is the clearest ancestor of everything this company is trying to do. The ethos that hums under this whole book — that food should be grown and prepared to carry the most nourishment a body can draw from it — is not an idea we invented. It is the *milpa's* idea, the ancient intercropped field where corn, beans, and squash grow together and complete each other's nutrition, the chile and the tomato tucked among them, a whole and self-sufficient table that needed nothing added to be nourishing. The lime-steeped kernel is that ethos made edible, five thousand years before we arrived to put a number on anything.

And corn is our horizon, not our achievement, and we will not pretend otherwise. It sits in the farthest tier of the Beyond-Peppers roadmap — *Corn* **Storm**, a frontier-synthetic concept of ten to twelve genes on a 48-to-72-month timeline — because carrying the chile's whole lesson into a grass, a monocot whose metabolism is a world away from a pepper's, is the long reach of everything the platform knows. We have not built it, and so it has no IFI profile and no SKU, and it will get none here; the roadmap is a statement of ambition, honestly labeled, not a catalog of things that exist. What we will say is that the ambition is exactly the milpa's own, carried forward: to grow the staple so it holds the most of what a body needs. The chiles are what we can design today. The masa beneath them is the reminder of where the reverence started — and of how far this language still has to run.

Chapter 15 · The Tomato, Restored — *the savory heart.*

If corn is the plate, the tomato is the pot — the base of the roja, the body of a *sopa*, the quiet savory floor under a hundred dishes. And the tomato is the plant on which this whole platform first proved that the method reaches past peppers, which makes it worth understanding in full. The tomato's gift to cooking is **umami**: the deep, savory, mouth-filling fifth taste, carried by **free glutamate** and read by **mGluR1** (and by the **TAS1R1·TAS1R3** heterodimer). A vine-ripened tomato, warm from the sun, is one of the richest plant sources of free glutamate there is — which is precisely why a tomato tastes *savory* in a way no other fruit does, and why it anchors so much of the world's cooking.



The tomato in cross-section: the jelly around the seeds holds much of the free glutamate — the savory depth that modern supply chains quietly strip away.

The tragedy of the modern tomato is that we engineered the savor *out* of it without meaning to — not with genes but with logistics. A tomato bred to ship is picked hard and green, gassed to color in transit, and chosen for shelf life over flavor, and somewhere in that chain the free glutamate collapses: a supermarket tomato can carry a fraction of the umami of a vine-ripened one, as little as a few percent of what the plant is capable of. Our tomato work — **2,040 engineered constructs**, the easiest organism in the library to work in, expressing on sweetness, umami, and the composites — is best understood not as addition but as *restoration*: pushing the free-

glutamate content back up through the plant's own glutamate machinery (the **GAD** and **GDH1** routes that the tomato already runs) to where a sun-ripened heirloom once sat, and holding it there regardless of how the fruit is picked and shipped. On the Index that is a move from IFI-U near 300, where the shipped supermarket tomato languishes, back up toward 2,600 — the savory depth the truck took, grown back in.

The biochemistry of that restoration runs through machinery the tomato already owns. Free glutamate in the fruit is governed by a small set of enzymes — glutamate decarboxylase (**GAD**) and glutamate dehydrogenase (**GDH1**) chief among them — sitting at the junction of the amino-acid pools and the GABA shunt, the loop in which glutamate is turned to GABA and back. Nudge that balance toward accumulation and the fruit holds more free glutamate at the moment it is eaten; it is restoration through the plant's own routes, not an additive dosed at a factory — the whole difference between growing savor and spraying it on. And there is a multiplier waiting. Glutamate's umami is *synergistic* with the ribonucleotides inosinate (IMP) and guanylate (GMP), and the synergy is not additive but closer to multiplicative — a little glutamate with a little GMP produces an umami several times louder than either alone, a relationship clean enough that food scientists write it as an equation. A restored tomato finished with a handful of toasted mushroom (rich in GMP) is a dish tuned, knowingly or not, to that multiplication, which is how the humblest *sopa* built this way can taste as though it had been simmered on bones.

TOMATO	THROUGH	IFI-U
Supermarket, shipped	bred for the truck; free glutamate collapsed	~300
Restored (Caldera)	the plant's own GAD / GDH1 routes, held through shipping	~2,600

Those two rows are the locked figures — the floor the modern tomato fell to and the restored savor our model predicts it holds at. The wider *Volcanic* line names the staged concepts of the roadmap's T1 Solanaceae Core — **Ember, Magma, Pyroclast, Caldera, Krakatoa** — the ladder by which that restoration is built out variety by variety; Caldera is the rung that exists today, and we will not print a hard score on a rung that does not.

There is one more piece of umami chemistry a cook should feel, because it is why a tomato and a mushroom together taste like far more than either alone. Glutamate's savor is *synergistic* with the ribonucleotides — the inosinate (IMP) and guanylate (GMP) that mushrooms, in particular, carry — and the synergy is not additive but multiplicative: a little of each produces an umami several times louder than the sum. A salsa roja built on a restored tomato, finished with a handful of toasted mushroom, is a dish deliberately tuned to that multiplication. The old cooks found the pairing by taste. The Index shows you the gear it is turning.

The tomato's own name carries its birthplace, and the history is a small correction worth making. The word *tomato* comes from the Nahuatl *tomatl* — and the original *tomatl* was in fact the tomatillo, the husked green fruit of the last chapter's verde; the red one the Aztecs

called *xitomatl*, "plump tomatl," which is where *jitomate*, the word much of Mexico still uses, descends from. Both travelled out of this soil after the conquest, and the red one went on to become so central to the cooking of Italy and Spain that the world forgot it was American at all — a forgetting this whole library is, in its way, built to undo. When we restore a tomato's umami, we are returning a Mesoamerican fruit to the savor it carried before five centuries of travel and breeding-for-shipping wore it thin. The gene is new; the intention is very old.

Sopa de Tortilla

Serves 4 · 40 minutes · the broth that proves a tomato can carry a whole bowl

A tortilla soup is a test of a tomato: there is almost nothing to hide behind — a tomato-and-chile broth, crisp tortilla strips, and the garnishes you love. Built on a restored tomato it needs no stock cube and no shortcut to taste deep.

You need

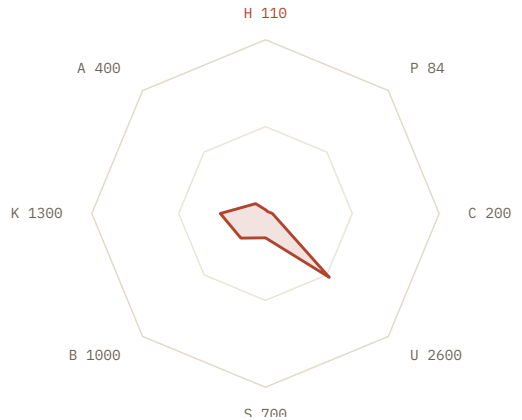
6	ripe Caldera tomatoes (or best umami-restored tomato)
2	guajillo chiles, stemmed and seeded
2	pasilla chiles, stemmed and seeded (plus 1 to fry for garnish)
1/2	white onion · 3 cloves garlic
4 cups	vegetable stock or water · 1 epazote sprig if you have it
	4 corn tortillas, cut in strips and crisped · salt
	to finish: avocado, queso fresco, crema, lime

Make it

1. Char the tomatoes, onion, and garlic on a dry comal. Toast the guajillo and pasilla a few seconds and soak 10 minutes.
2. Blend the charred vegetables with the soaked chiles and a little stock until smooth. Fry this purée in a little oil over medium-high heat, stirring, until it darkens and thickens — 8 minutes.
3. Add the stock and the epazote; simmer 20 minutes and salt to taste. Serve over crisp tortilla strips with avocado, cheese, crema, a crumbled fried pasilla, and lime.

Why it works — The whole bowl rests on the tomato, and a Caldera restored to IFI-U 2,600 carries it alone — the broth reads as long-simmered and meaty with nothing of the sort added, because the savor is the plant's own, grown back to where the vine once held it. The guajillo and pasilla sit low at IFI-H 110 so the soup is warming, not hot, and the avocado and crema fold in a cooling richness at the end.

IFI PROFILE



IFI-H	110
IFI-P	84
IFI-C	200
IFI-U	2,600
IFI-S	700
IFI-B	1,000
IFI-K	1,300
IFI-A	400

Chapter 16 · The Aromatics — *oregano, canela, and the vanilla that began here.*

A Mexican kitchen is held together by a handful of aromatics that most cooks never think to measure, and reading them on the Index reveals a quiet secret: several of the things we call "spice" in this cuisine are, at the receptor, the same channel the fresh chiles fire. They are pungency, not heat — and understanding that is what lets a cook build brightness into a dish without building burn.

Mexican oregano is the first of them, and it is not the Mediterranean herb at all. It is *Lippia graveolens*, an entirely different plant from *Origanum vulgare*, brighter and more floral and more citric, and the chemistry behind that character is **carvacrol** and **thymol** — monoterpenoid phenols that are **TRPA1** agonists. So the lift Mexican oregano gives an adobo or a pot of beans is **IFI-P**, pungency, the same fast top note as a raw chile, which is exactly why it reads as *sharp and alive* over a dark sauce rather than merely herbal. **Canela** — true Ceylon cinnamon, *Cinnamomum verum*, soft enough to crumble between your fingers, not the hard cassia sold elsewhere — brings **cinnamaldehyde**, another TRPA1 agonist, which is why a stick of it in a mole or a pot of *champurrado* reads as a bright warmth you feel as a top note and not as sweetness. **Epazote**, the pungent herb cooked with black beans, carries carvacrol of its own; even the anise note of a toasted **avocado leaf** (estragole) plays in this register. A whole family of Mexican aromatics, it turns out, speaks on one axis the Index can now name.

The register runs deeper than oregano and canela. *Hoja santa*, the great soft "holy leaf" folded around fish and melted into green moles, carries safrole and gives a sassafras-and-anise lift that is pure southern Mexico. A dried *avocado leaf*, toasted and laid into a pot of black beans, brings its own anise note from estragole. Each of these is aroma more than taste, read mostly by the nose — but each also plays, faintly, in the TRPA1 register the Index names IFI-P, which is why they all read as *bright* over something dark and slow. And here is a place where reading the chemistry is also a small matter of care: the hard *cassia* sold as cinnamon across much of the world carries coumarin, which true Ceylon *canela* holds only in traces — one more reason the Mexican kitchen's insistence on real, crumbly canela is not fussiness but a quiet wisdom about what you ask a body to take in, day after day.

And no account of this kitchen's aromatics is honest without *epazote*, the rank, green, unmistakable herb that is to a pot of black beans what bay is to a European stock. Its pungency comes from ascaridole and carvacrol — TRPA1 again, the IFI-P register — and its traditional marriage to beans is not only flavor: the herb has long

been held to ease the digestion of legumes, one of those folk pairings in which a carminative chemistry and a culinary instinct turn out to be the same knowledge reached by taste. It is a strong, love-it-or-leave-it green, and it is one more voice in the TRPA1 chorus — oregano, canela, hoja santa, avocado leaf, epazote — that this cuisine has conducted for centuries without ever having had a name for the channel they all sing on.



Vanilla, native to Veracruz: the world's most complex flavor began in the same soil as the chile, and the two are written by the same six enzymes.

And then there is vanilla, which is not a footnote to this cuisine but a native of it — a fact the world has almost entirely forgotten. The orchid *Vanilla planifolia* is Mesoamerican, and it was first cured into the fragrant pod we know by the **Totonac** people of Veracruz, long before it was carried anywhere else; the world's most complex and most counterfeited flavor began here, in the same soil as the chile. On the Index we read vanilla on **IFI-K**, kokumi — the round, lingering, mouth-filling body it lends through the **CaSR** receptor, the quality that makes a custard or a *flan* or a cup of spiced chocolate feel *complete* rather than merely sweet. Vanilla does not taste of much on its own; what it does is make everything around it feel whole, which is the definition of kokumi.

How that pod comes to smell of anything is a story of patience that rhymes with everything else in this book. On the living vine the orchid holds its vanillin locked away and odorless, bound to a sugar as **glucovanillin**; the green pod has almost no scent at all. Only curing frees it — months of a daily cycle, the pods scalded or sweated and then laid out to dry and rest, over and over, during which the plant's own enzyme **β-glucosidase** cleaves the sugar away and releases free vanillin while hundreds of lesser aroma compounds build alongside it into the thing we call, reductively, "vanilla." The flower is just as demanding: *V. planifolia* is pollinated in its homeland by specific native bees and hummingbirds, and everywhere else on earth it must be hand-pollinated, one bloom at a time, in the few hours the flower is open — a method worked out by a young enslaved boy, Edmond Albius, on Réunion in 1841, and still used unchanged across the world. The most counterfeited flavor on the planet is counterfeited precisely because the real one asks for this much hand and this much time. Reading it on IFI-K shortcuts none of that. It only tells you, at last, what the pod is *doing* when it makes a custard feel whole.

There is a kinship here worth ending the chapter on, because it is the deepest rhyme in the whole book. The same phenylpropanoid branch — **PAL through COMT**, the six-enzyme road of Chapter 3 — that writes the **vanillin** at the heart of this orchid also writes the **vanillylamine** at the heart of capsaicin. The sweetness and the fire that Mexico gave the world are, down at the molecule, built from the same grandmother pathway, diverging only in their final steps: one road ends at the aldehyde that perfumes a custard, the other at the amine that becomes a flame. Vanilla and the chile are cousins, and they were raised in the same valley. We did not design that rhyme. We only learned, at last, to read it — and reading it is the whole reason this platform can carry the chile's method to the orchid, and to the tomato, and one day to the corn.

Chapter 17 · Consistency, Compliance & the Table — *the number as a promise.*

For most of this book the Index has been a tool of design — a way to choose a heat, balance a sweetness, subtract a bitterness. But its quietest and perhaps most consequential gift is not design at all. It is *consistency*, and consistency is what turns a beloved recipe into a product a brand can actually stand behind.

Recall the number from Chapter 4: a wild superhot chile swings roughly **42%** in heat from plant to plant and season to season, while our engineered cultivars hold to a coefficient of variation of **≤7%**. Live with that first figure for a moment from the point of view of a salsa maker. A 42% swing means the hot sauce you formulate in the spring, taste, and love can ship in the winter tasting meaningfully different — hotter or milder — through no error of your own, because the chile beneath it moved. It is the single hardest problem in building a chile product at scale, and it is why so many beloved small-batch sauces never survive their own growth. A ≤7% CV is the promise that the chile will not move: that the heat you specify is the heat you get, this batch and the next, which is what lets a cook's recipe become a formulator's spec. Every IFI figure in this book is really a pair of promises — *this* loud, and *this* reliable.

It is worth being exact about what the reliability number means, because exactness is the point. A coefficient of variation is simply the standard deviation divided by the mean — the spread of a batch expressed as a fraction of its center — so a ≤7% CV says the overwhelming majority of fruit from a cultivar falls within a narrow band around its specified heat, tight enough that a formulator can treat the IFI-H as a fixed input rather than a moving target. At 42%, the wild figure, the band is so wide that two fruit from the same plant can differ by more than the gap between a jalapeño and a serrano; at 7%, the difference between fruit falls below what a palate can reliably detect. That is the whole of what reproducibility buys, and it is why the figure sits in the same canon as the heat itself.

It is worth seeing what that reliability unlocks for a product line, because it is the whole commercial point of a readable, settable heat. A sauce brand can design a *ladder* of its own — a mild at IFI-H 150, a medium at 330, a hot at 900 — and know that each tier will taste, batch after batch and year after year, like the tier the label promises, because the chiles beneath them do not drift. The same recipe, the same fruit, three chosen rungs: a range built by moving one dial rather than by sourcing three unreliable crops and hoping. That is heat laddering carried from the family table, where it let one bowl reach everyone, to the shelf, where it lets one brand offer a whole audience its own comfortable rung. Of the platform's roughly 19,000 engineered constructs, about a thousand are live and

purchasable today; a cuisine's worth of laddered sauces is a small, buildable corner of that library — and, from seed to bottle, a readable one.

The frameworks around the work follow from what it actually is. Because these are foods and not drugs, they live under food's rules — compositional and allergen transparency, and the bioengineered-food disclosure that applies to engineered crops — and the safety case is built in the open, on the published papers rather than behind them. The guardrail we hold hardest is the one that is ours alone to hold: we describe attributes, never outcomes. A tomato restored to its savor is a tomato that tastes of more. It is not a treatment, a cure, or a claim, and we will not let the warmth of the writing ever imply that it is. These are computational designs; Scoville Splice's cultivars and constructs have not been experimentally validated in a laboratory.



The sequencer bench: every number in this book is also a QA specification, held to ≤7% so the heat you design is the heat you ship.

It is worth being plain about what these cultivars are and are not, because the plainness is part of the respect we owe a reader. They are **whole plants, grown from seed** — not additives, not extracts, not flavorings dosed into a vat. The heat and the depth are grown in the field and the greenhouse, by the plant's own machinery, which we have read and, at a few precise loci, rewritten. That matters for how the work meets the world: these are foods, subject to food's own disclosure frameworks (including bioengineered-food labeling where it applies), developed on published science — **21 peer-reviewed papers**, released on Zenodo under CC BY 4.0, and **3 patents filed** — rather than on secrecy. The library behind this book is large and

precisely counted, and we hold to one canonical set of figures everywhere, because across a shelf of books drift is the one thing that reads as sloppy:

FIGURE	VALUE
Engineered constructs (platform-wide)	~19,000
Live / purchasable today	1,000
Total SKUs catalogued	78,800
Host organisms validated	42
Sensory axes	8
Batch coefficient of variation	≤7%

For the Mexican kitchen specifically, the organisms this book draws on sit within that library at known weights — a map of where the design effort has actually gone:

ORGANISM	CONSTRUCTS	PRIMARY AXES	DIFFICULTY
Pepper	1,060	all eight	Native
Habanero (*C. chinense*)	3,190	F / M	Hard
Tomato	2,040	S / U / F / M	Easy
Garlic	560	K / P	Moderate
Potato	80	B	Easy
Onion	40	K	Moderate
Oregano	40	P	Hard
Cinnamon	40	P	Hard
Vanilla	40	K	Hard

One last line, and it is the most important compliance note in the book because it is really an ethical one. The nourishment that hums under every chapter here — the restored umami, the released niacin of the nixtamal, the whole-plant care, the sense that food should be grown to hold the most a body can draw from it — is a **value and an intention, never a claim**. We do not say that any of this cures, detoxes, treats, or prevents anything, because it does not, and because a kitchen that respects its reader does not dress an intention up as a promise it cannot keep. What we design is flavor, measured honestly. That the flavor is grown into plants cared for enough to also carry real nourishment is the ethos of the house — the milpa's ethos, carried forward — and it is offered exactly as that: a way of cooking, given to you to do with as you will.

Chapter 18 · A Closing Grace — *the chile as generosity.*

We did not write this book to improve on a tradition older and wiser than any laboratory. We wrote it because we fell in love, the way everyone does, with the chiles of this place — with the dark raisin of an ancho, the berry of a guajillo, the leather of a chipotle, the flowered fire of a Yucatán habanero — and because, for the first time, we could hold what we loved up to a number and understand it. Not to replace the cook who knows the canon by heart; to stand beside her. To let a salsa brand carry, batch after batch, the exact heat a grandmother built by feel. To let a table of mixed tolerances share one honest bowl. To let a dark mole be toasted brave and never turn bitter. To hand a fermenter a chile whose fire has stopped drifting, and a formulator a recipe that has become a spec without becoming any less a recipe.



The greenhouse at the hour the work is quietest — where a family that reveres what it grows writes the mathematics of flavor the way you'd write about something you love and want to nourish you.

That is what the ladder is really for. Heat, in this cuisine, was never an assault — it was an invitation, a thing you offered across a table to the people you were feeding, a sensation made safe enough to become a pleasure given on purpose. A number does not make that gift less generous. It makes the generosity *aimable*: this much warmth, for this table, tonight, grown into a plant that was also grown to nourish the body receiving it. The chile taught the whole world that a sensation could be a pleasure chosen rather than a danger suffered, and that is the oldest lesson in this book and still the truest. All we have added is the grammar to give it exactly — to say, at last and on purpose, *this* loud, and *this* reliable, and *this* kind.

If there is a single conviction this family would want left on the table when the plates are cleared, it is that measuring a thing and loving it were never opposed. We learned to read the chile because we loved it — the way you learn the grammar of a language you mean to live inside, not to speak more coldly but to be understood more exactly, and to be able to say the tender thing again tomorrow. The number is a servant of the generosity, never its replacement. A heat held steady is a promise kept to whoever you are feeding; a bitterness quieted is a harshness you have chosen to spare them; a tomato grown back to its savor is a small act of giving the body more of what it came for. That is the whole ethic of this house, and it is older than any of our instruments: cook so that the eating nourishes, and give it with intention.

Cook these for the people you love. Read the numbers if they help you and forget them the moment the cooking starts. That was always the whole point of measuring anything: not to replace the feeling, but to be able to give it again, and again, exactly — to whoever sits down at your table next.